Echinococcosis

Disease Monograph Series – 12

Parasite | *Echinococcus granulosus* | Zoonotic | Sheep | Cattle | Goats | Pigs | Dogs | Humans

IDRC | Bartay

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Acronyms

AE	Alveolar echinococcosis
AU	African Union
AU-IBAR	African Union Inter-African Bureau for Animal Resources
AU-PANVAC	African Union – Pan African Vaccine Centre
CE	Cystic echinococcosis
CVO	Chief Veterinary Officer
DALY	Disability-Adjusted Life Years
DG	Director General
DoI	Duration of immunity
DVS	Director Veterinary Services
ELISA	Enzyme-linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations
IM	Intramuscular
NGO	Non-governmental organization
OIE	World Animal Health Organization
PCR	Polymerase chain reaction
SHF	Small holder farmer
TPP	Target Product Profile

UM	University of Melbourne
WHO	World Health Organization of the United Nations

Executive Summary

Etiology and epidemiology

Echinococcosis, also called hydatidosis or hydatid disease, is a zoonotic disease caused by various species of cestode parasites of the genus *Echinococcus*. It is recognised by the World Health Organization (WHO) as one of 16 diseases or disease groups considered to be “Neglected Tropical Diseases”.

While there are several pathogenic species of *Echinococcus*, with four species considered to infect humans, most of the global concern caused by echinococcosis is due to infection with *E. granulosus*, and its ability to generate hydatid cysts in humans. *E. granulosus* causes what is known as cystic echinococcosis (CE). This report focuses on echinococcosis caused by *E. granulosus*. Hydatid disease occurs in Africa, Europe, Asia, the Middle East, Central and South America. *E. granulosus* is transmitted between the definitive hosts which are the canids, dogs mainly, and herbivorous intermediate hosts, in most cases sheep and goats. The parasite is transmitted to dogs when they ingest the organs of other animals that contain hydatid cysts. The cysts develop into adult tapeworms in the dog. Infected dogs shed tapeworm eggs in their feces which contaminate the ground. Sheep, cattle, goats, and pigs ingest tapeworm eggs in the contaminated ground; once ingested, the eggs hatch and develop into cysts in the internal organs. The most common mode of transmission to humans is by the accidental consumption of soil, water, or food that has been contaminated by the fecal matter of an infected dog. *Echinococcus* eggs that have been deposited in soil can stay viable for up to a year.

With the advent of DNA technology, genotypes have been defined. Of these, it has been determined that the G1-3 genotype(s) are responsible for up to 88% of all human cases of hydatid disease worldwide, followed by a camel and goat transmitted genotype, G6, causing 7% of human infections and a pig transmitted genotype, G7, causing 3% human infections.CE in humans is a chronic disease. Humans with CE often remain asymptomatic until hydatid cysts containing the larval parasites grow large enough to cause discomfort, pain, nausea, and vomiting. The cysts grow over the course of several years before reaching maturity and the rate at which symptoms appear typically depends on the location of the cyst; sudden death may occur. In livestock symptoms are likely to be the same as in human, while in dogs there are no clinical signs.

Diagnostics

A wide range of diagnostic tools exists for human. For livestock, most of the diagnostic tests described in the abundant literature on the subject are not reliable, mainly due to a weak or no specific antibody response to the disease in many infected animals and because of the almost ubiquitous infection of livestock species with closely related, and antigenically cross-reacting, taeniid cestode species. Post mortem examination of liver and lung tissues remains the only reliable method for diagnosis of infection in livestock animals. Similarly in dogs, because of the fact that eggs of all taeniid cestode species are morphologically indistinguishable and wherever *E. granulosus* is transmitted, so are a number of other species of taeniid cestode; traditional egg examination of faeces is not reliable. Definitive diagnosis in dogs can only be made by examination of the small intestine at necropsy, or examination of worms voided in an intestinal purge induced after administration of appropriate drugs. PCR-based methods are also valuable, and specific, although they lack sensitivity in the case of low worm burdens. The progress made to date in the development of more reliable diagnostic tools requires further work, aspects of which are discussed in the present monograph.

Incidence / Prevalence and Impact

Under-reporting is a major problem for CE globally: this is clearly visible in the data from the OIE and the AU-IBAR. In many countries where there are no reports on animal cases, such as in South Africa, there are human cases reported. It is presumed that livestock reports are based on slaughter findings, but this is not certain as no details on the information are available. In most cases conclusions are drawn from human cases even though there, also no reliable data are available. The worldwide incidence of CE is estimated to amount to 100,000-300,000 cases annually, with the disease known to occur in all continents and in at least 100 countries.

According to a 2015 WHO report on neglected tropical diseases, in regions where cystic echinococcosis is endemic the incidence in humans can exceed 30/100 000 person-years; prevalence as high as 5–10% may occur in parts of South America, Central Asia, China and Africa. The postoperative death rate for surgical patients is 2.2%; 6.5% of cases relapse after intervention and require prolonged recovery time. Human echinococcosis can be life-threatening if undiagnosed and untreated. Treatment often includes costly surgery. Taking into consideration the public health impact, condemnation at slaughter, production losses and other economic burden in developing countries, other studies estimate the annual global economic losses due to CE in livestock to be over US$2Billion.

Control

Because humans infected with CE pose no risk to other humans, all efforts to control transmission of the disease must be implemented either towards reducing the exposure of humans to the parasite (sanitation, exposure to infected dogs) or intervention measures directed towards the animal hosts. From experiences gained in some countries that had implemented control programs, a combination of approaches is required, taking into consideration local circumstances, socio-political and other realities and constrains. Situations such as the presence of stray dogs in certain countries would add to the difficulties in prescribing universal approaches.

Treatment: In humans, treatment with essentially Albendazole forms an important aspect of disease management. However, to be effective the drugs are required to be given in large amounts over long periods of time. No practical treatment has been developed for livestock animals. Infected dogs can be treated and 100% cured with a single dose of Praziquantel. However, there is no effective immunity in dogs, thus exposing them to re-infection with *Echinococcus,* in the absence of an effective control program.

Prophylaxis: A sheep vaccine has been developed and evaluated in several situations, showing that it can greatly reduce transmission of *E. granulosus* by livestock animals (including goats and cattle challenges with the G1-3 genotype(s)).

A number of options and strategies for control programs at national, sub-national or regional level can be considered. These would include elements of

- Control of non-owned dogs
- Prevention of dogs gaining access to infected offal
- Treatment of dogs
- Quarantine of infected livestock
- Vaccination

Mathematical modelling of the transmission parameters for CE using various CE control options including the EG95 vaccine, showed that the use of vaccination together with relatively infrequent treatment of dogs, provided the optimal level of control with a relatively minimal cost. Although wildlife is known to contribute to some degree to CE transmission in many parts of the world, wildlife transmission is not considered to be a major source of human infection in highly endemic regions of the world. CE control measures are more appropriately directed towards domestic transmission of the disease rather than sylvatic transmission.

Current Vaccines

There is no existing vaccine to prevent or reduce *Echinococcus* infection in dogs. There is little evidence to support the existence of protective immune responses against infection with *Echinococcus* or other taeniid cestode species in their definitive host and it appears that the prospect for development of a vaccine against the adult parasite, which resides in the intestinal lumen, is poor. A livestock vaccine based on a recombinant antigen from the oncosphere life-cycle stage of the parasite, known as EG95, has been developed by the University of Melbourne and successfully evaluated in independent experimental trials undertaken in sheep in Australia, New Zealand, Argentina, Chile, Iran, China and Romania, and also in goats and cattle. The vaccine has demonstrated a reliable, high level (>90%) protection against a challenge infection with *E. granulosus.* The EG95 vaccine is produced by local manufacturers in Argentina and China. However, neither company appear to be GMP compliant, and GCP data on these vaccines (that have been formulated different from the original) are not available. Field data is also very limited. There is no to date a human vaccine, although the immunological characteristics of *E. granulosus* infection in humans would suggest that the EG95 vaccine would likely be effective in humans.

The future of cystic Echinococcosis vaccines and vaccination

Data generated to date, point towards the need for combination vaccines, produced under GMP, and evaluated in a natural transmission environment. A clear opportunity exists for the development of combination vaccines incorporating EG95 into existing clostridial vaccines commonly used in young livestock that are at risk of echinococcosis. Such combinations provide a potential solution to the lack of economic incentive perceived by livestock owners to prevent echinococcosis in their animals.There is a need for field validation of the effectiveness of livestock vaccination with the EG95 vaccine in order to formulate new guidelines for control of the disease. There is a need to evaluate whether the current EG95 vaccine is effective against other genotypes, as to broaden its scope.

Clinical disease overview

Echinococcosis refers to a group of diseases caused by various species of cestode parasites of the genus *Echinococcus*. Alternative nomenclatures for these diseases include hydatids and hydatid disease. The name echinococcosis was adopted after an expert committee established by the World Association for the Advancement of Veterinary Parasitology published a Standardized Nomenclature of Animal Parasitic Diseases [1]. The committee's recommendations have not been accepted universally and the term hydatid disease remains in use, as well as echinococcosis. Echinococcosis in humans is a zoonotic disease. It is formally recognised by the World Health Organization (WHO) as one of 16 diseases or disease groups considered to be Neglected Tropical Diseases and the WHO is actively promoting the development and implementation of strategies to decrease the incidence of echinococcosis [2]. The WHO and other agencies have issued joint, comprehensive, official Guidelines for Surveillance, Prevention and Control of Echinococcosis/Hydatidosis [3], however they are in dire need of review and updating. It is likely the WHO would welcome and value assistance in updating these guidelines (M. Lightowlers, personal communication).

Etiology and Epidemiology

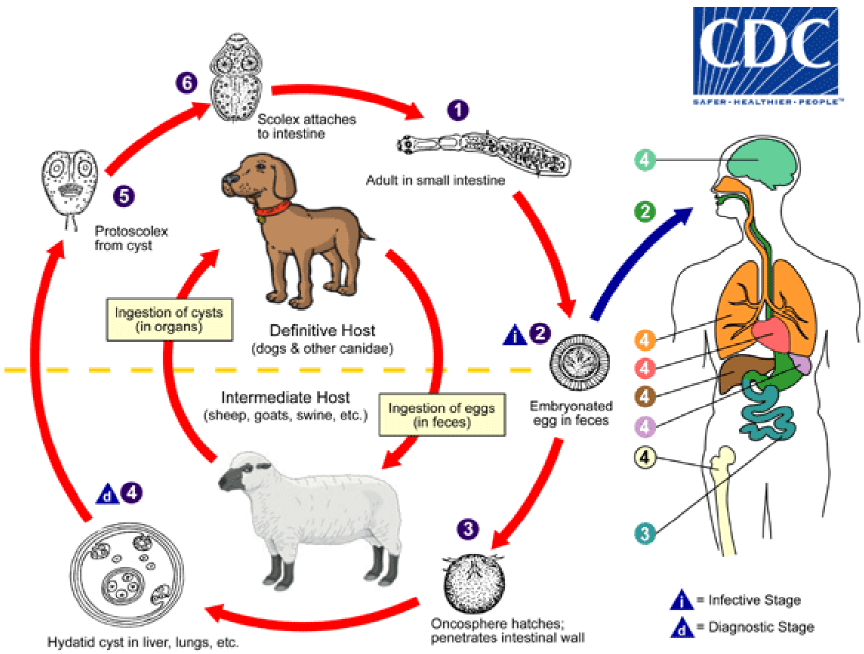
Several species of *Echinococcus* cause hydatid disease. Taxonomy within the genus *Echinococcus* is complex and evolving. Over much of the preceding century, four species were considered to infect humans: *Echinococcus granulosus, Echinococcus multilocularis, Echinococcus vogeli* and *Echinococcus oligarthrus*. The latter two species are restricted to Central and South America and are relatively rare. *E. multilocularis* causes alveolar echinococcosis (AE), a highly dangerous, metastasising form of disease. It is restricted to the northern hemisphere and, while it is endemic in many central and northern European countries, as well as central Asia and North America, other than in some relatively restricted parts of China and Tibet, its prevalence in humans is in the order of 0.1 per 100,000 population. More recently a new species similar to *E. multilocularis* has been identified from the Qinghai-Tibet plateau in China, *Echinococcus shiquicus* [4]. *E. granulosus* causes what is referred to as cystic echinococcosis (CE).

Most of the global concern caused by echinococcosis is due to infection with *E. granulosus*, and due to it causing hydatid cysts in humans.

Livestock play a critical role in transmission of *E. granulosus* that leads to human disease, and echinococcosis in humans is a substantial burden on poor rural pastoral communities. *E. granulosus* is transmitted between canid definitive hosts and numerous species of mainly herbivorous hosts that act as intermediate hosts. Worldwide, sheep and goats play the most dominant role in transmission of *E. granulosus*. Dogs harbour a small tapeworm in the small intestine. Mature, infective eggs are released with the faeces of an infected dog. Following ingestion of the egg by a suitable species of intermediate host, the parasite within the egg, known as an oncosphere, is released, becomes active, penetrates the gut and enters the blood stream. The oncosphere exits the circulation within the tissues and establishes a cystic metacestode stage which matures slowly, only becoming fertile and able to achieve transmission after a developmental period lasting more than a year. The liver and lungs are the most common sites in which the cysts (hydatid cysts) develop, although cysts may occur in any body organ. Ingestion of mature, infective cyst contents by a dog leads to the development of the tapeworm stage, completing the life cycle. The common use of shepherd dogs perpetuates transmission of *E. granulosus* such that the disease is endemic throughout the world where pastoral activities predominate.

E. granulosus has long been known to be a pleomorphic species, with what has been described as 'strains' that differed in host preference and other attributes. Following the advent of DNA-based taxonomic tools, a variety of genotypes have been defined, several of which are believed to warrant elevation to species status [5]. Many of these genetic variants rarely or never cause human disease [6]. One genotype is responsible for almost all human cases of hydatid disease: the G1-3 genotype(s), which causes 88% of infections worldwide. A camel and goat transmitted genotype, G6, causes 7% of human infections and a pig transmitted genotype, G7, causes 3% human infections that have been genotyped up until 2014 [6]. The G6 and G7 genotypes are closely related and the species name *Echinococcus canadensis* has been suggested for these genotypes. The G1-3 genotype(s) is referred to as *Echinococcus granulosus sensu stricto* or *E. granulosus s. s*. Hereinafter, the terms echinococcosis and CE will refer to infections with *E. granulosus s. s*. unless otherwise indicated.

Transmission of *E. granulosus s. s.* occurs between dogs and livestock animals in a prey-predator cycle (Figure 1). Transmission does not occur between dogs, nor between infected livestock animals or between humans. Accidental ingestion of parasite eggs from the faeces of an infected dog transmit the disease to both livestock and humans. Transmission to dogs occurs through them ingesting hydatid cyst material in the viscera (typically) of infected livestock. Deliberate feeding of farm dogs with unsightly offal containing hydatid cysts has been a major cause of CE transmission leading eventually to human disease. Scavenging of animal carcases by farm dogs, wild and non-owned canids, and peri-urban dogs also contributes substantially to CE transmission.



The adult *Echinococcus granulosus* (3 to 6 mm long) ❶ resides in the small bowel of the definitive hosts, dogs or other canids. Gravid proglottids release eggs ❷ that are passed in the feces. After ingestion by a suitable intermediate host (under natural conditions: sheep, goat, swine, cattle, horses, camel), the egg hatches in the small bowel and releases an oncosphere ❸ that penetrates the intestinal wall and migrates through the circulatory system into various organs, especially the liver and lungs. In these organs, the oncosphere develops into a cyst ❹ that enlarges gradually, producing protoscolices and daughter cysts that fill the cyst interior. The definitive host becomes infected by ingesting the cyst-containing organs of the infected intermediate host. After ingestion, the protoscolices ❺ evaginate, attach to the intestinal mucosa ❻, and develop into adult stages ❶ in 32 to 80 days.

The same life cycle occurs with *E. multilocularis* (1.2 to 3.7 mm), with the following differences: the definitive hosts are foxes, and to a lesser extent dogs, cats, coyotes and wolves; the intermediate host are small rodents; and larval growth (in the liver) remains indefinitely in the proliferative stage, resulting in invasion of the surrounding tissues. With *E. vogeli* (up to 5.6 mm long), the definitive hosts are bush dogs and dogs; the intermediate hosts are rodents; and the larval stage (in the liver, lungs and other organs) develops both externally and internally, resulting in multiple vesicles. *E. oligarthrus* (up to 2.9 mm long) has a life cycle that involves wild felids as definitive hosts and rodents as intermediate hosts. Humans become infected by ingesting eggs ❷, with resulting release of oncospheres ❸ in the intestine and the development of cysts ❹, ❹, ❹, ❹, ❹, ④ in various organs.

Figure 1: Life cycle of *E. granulosus* (Source CDC: http://www.cdc.gov/parasites/ echinococcosis/biology.html

E. granulosus eggs are considered to be highly susceptible to desiccation and heat as are the eggs of other species of taeniid cestode. Little direct information is available about the survival of *E. granulosus* eggs *per se*. At least some eggs of the related species *Taenia hydatigena* are known to survive on pasture for at least 12 months in the relatively favourable conditions pertaining in New Zealand [7]. A single publication [8] suggests a more substantial ability of *E. granulosus* to persist in the environment, however those findings are at odds with substantial evidence to the contrary and the matter remains to be resolved by further study.

Relevance to vaccine protection: An effective vaccine has been developed which can prevent or reduce E. *granulosus s.s.* infection in sheep and other livestock species [9]. The vaccine, based on a recombinant antigen known as EG95 (developed from a G1-3 genotype), has been highly effective in experimental vaccine trials carried out in sheep in several countries. The mRNA encoding the EG95 homologue has been cloned and sequenced from *E. canadensis* (G6 and G7) and found to be different both in amino acid sequence and antigenicity [10]. It is yet to be determined whether the EG95 vaccine is capable of protecting animals against a heterologous infection with *E. canadensis*, or whether the homologue from *E. canadensis* would be effective as an homologous vaccine.

Clinical Signs

In most species of animal, and in humans, CE cysts grow slowly; macropod marsupials appear to be an exception [11]. Hence, CE is a chronic condition. Symptoms in humans vary greatly depending on the location, size and number of cysts. Upper abdominal pain is a common initial symptom of liver infections. Sudden death may occur due to anaphylactic-like reactions following accidental rupture of a hydatid cyst. Patients may asphyxiate following the rupture of a lung cyst. Infected livestock are likely to suffer similar clinical symptoms to those seen in humans, however differential diagnosis of a case of sudden death in a sheep or goat is rarely investigated. Dogs exhibit no clinical symptoms from the presence of *E. granulosus* tapeworms.

Diagnosis

The OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals includes a chapter on Echinococcosis /Hydatidosis [12], however it needs to be updated. A comprehensive review on the topic of diagnosis has been published recently [13].

- Human: Excellent serological tests are widely available for diagnosis of human CE. These are supplemented by the use of imaging techniques and parasitological examination of samples removed during surgical procedures.
- Livestock: Despite many publications claiming the contrary, there are no reliable serological methods for diagnosis of hydatid infection in animals (M. Lightowlers, personal communication). The failure of serological diagnosis in animals arises due to two issues: a weak or non-existent specific antibody response to the disease in many infected animals [14][15] and because of the almost ubiquitous infection of livestock species with closely related, and antigenically cross-reacting, taeniid cestode species. A number of publications have described the use of ultrasonography for diagnosis of ovine echinococcosis, however the practical value of such an approach is unclear and ultrasonography does not permit reliable

detection of pulmonary echinococcosis. The only reliable method for diagnosis of infection in livestock animals is through post mortem examination of liver and lung tissues.

- Dogs: The eggs of all taeniid cestode species are morphologically indistinguishable and wherever *E. granulosus* is transmitted, so are a number of other species of taeniid cestode, notably *T. hydatigena* which has a very similar lifecycle. For this reason, traditional parasitological examination of faeces for the presence of eggs is unable to be used to specifically diagnose the presence of *E. granulosus*. Definitive diagnosis is made by examination of the small intestine at necropsy [13], or examination of worms voided in an intestinal purge induced by the drug arecoline hydrobromide. Following the discovery that dogs produce specific antibodies against infection with taeniid cestode parasites, including *E. granulosus* [16][17], serology was used in several epidemiological studies, however the methods used all relied on the application of inappropriate control samples [18] such that the validity of serological for diagnosis of infections in naturally infected dogs remains unclear. More recently, coproantigen (coproAg) detection methods and PCR analysis of faecal samples (coproPCR) have been developed which are more practical and provide good diagnostic sensitivity and specificity [13].

CoproAg tests are usually genus-specific for *Echinococcus* spp., although depending on the endemic region and study aims, coproAg tests have been developed and validated to test for infection with *E. multilocularis* in foxes and dogs or primarily for *E. granulosus*. For canine echinococcosis due to *E. granulosus* most authors report reasonable sensitivity (78–100%) and good genus specificity from 85% to greater than 95%, as well as a degree of pre-patent detection. Where cross-reactions occur these generally appear to be caused by infection with *T. hydatigena*, the most common taeniid of dogs, and attempts to improve specificity by using monoclonal antibodies in coproAg tests have not been able to eliminate this problem. CoproAg sensitivity broadly correlates with worm burden *of E. granulosus*, however some low intensity infections (worm burdens <50–100) may give false negatives in coproAg tests [13]. The commercial availability of coproAg tests has been problematic, with two kits discontinued in Europe (Chekit Bommeli, Switzerland; Genzyme VirotechGmbH, Germany). Currently commercial tests appear restricted to three coproAg kits for canine echinococcosis produced in China (i.e. Shenzhen Combined Biotech Co., Ltd.; Zuhai Special Economic Zone Haitai Biological Pharmaceuticals Co., Ltd.; Xinjiang Tiankang Animal Husbandry Biotech Co., Ltd.). These three China-based kits were recently assessed, against a parasitologically defined panel of dog faecal samples by the Institute of Parasitic Disease Prevention and Control, Sichuan CDC (also in China) and found to be of variable sensitivity and specificity, with the best kit providing a reported 60% sensitivity and 93% specificity [19]. There is a shortage of properly validated control samples from animals with parasitologically proven levels of infection and tests are commonly established in-house by researchers and laboratories associated with CE control activities however. Hence, the in-house tests rely on the published specificity/sensitivity results of other workers and hence are not adequately validated.

The advantage of coproPCR methods is their ability to differentiate *E. granulosus* infections specifically. Some of the published methods have also been able to differentiate infections with the different genotypes of *E. granulosus*. Due to the expense involved in using PCR as a diagnostic tool and the large numbers of samples that are required to be processed as part of a disease control program, the currently recommended methods are to screen canine faeces by coproAg testing and to confirm samples that test positive by coproPCR [13].

Main needs for diagnostics:

a) A coproAg test that is specific for *E. granulosus*.

b) A coproPCR test that is amenable to be undertaken by non-specialists which matches the sensitivity and specificity of coproPCR when it is undertaken in specialist laboratories.

Zoonotic disease

As indicated above, the global importance of echinococcosis is due, virtually entirely, to the impact of the disease on the human population. While the WHO clearly recognises CE as a global health concern and a burden on many poor pastoral communities, there is a deficiency in data available about the actual disease burden. The reasons for this situation are numerous, but major contributors are under-diagnosis, misdiagnosis and the chronic nature of the disease in most patients. Accounting for under-reporting, Budke et al. [20] estimate the annual global burden of CE to be >1M DALYs and >US$7.6B per year.

As already mentioned, the genotype cluster comprising genotypes G1, G2 and G3 is responsible for the great majority of human infections (88% worldwide) and the principal intermediate host is sheep. The closely related genotypes G6 and G7 cause a significant number of human infections (11% worldwide). The G6 strain is known from Africa and Asia, where it is transmitted mainly by camels and in some instances, goats.

Incidence and Prevalence in Selected Countries

Global

The worldwide incidence of cystic echinococcosis is estimated to amount to 100,000 to 300,000 cases annually [21] and is known to occur in all continents and in at least 100 countries. Increased prevalence of the parasite are found in parts of Europe, around Mediterranean region (variable between 1 and 8 per 100,000), the Russian Federation, China, Africa (prevalence >3%), Australia, and South America (9.2 per 100,000 population). In East Africa, Kazakhstan, Kyrgyzstan, Northwest-China, and Tibet, it has been observed that the rural populations are particularly at risk. Iceland and Greenland are free of echinococcosis, while only sporadic cases in domestic animals have been documented in New Zealand, Tasmania, southern Cyprus, Pacific region, and Caribbean [22].

The lack of data on echinococcosis arises from the absence of systematic programmes to generate these data, which remain fragmented. As a result, the global distribution of cystic echinococcosis has changed little since 2010. See Figure 2.

It is important to note, that human publications are mainly related to unusual cysts locations, or surgeries, and do not usually reflect the true incidence and/or prevalence.

Regional

Echinococcosis is a disease that produces almost no clinical signs in livestock; therefore reports to the OIE or AU-IBAR are very limited. It is presumed reports are based in slaughter findings, but it is not certain as no details on the information are available.

Due to the nature of the disease, it would be more appropriate to evaluate the prevalence/incidence of human cases; however, there is no reliable data either.

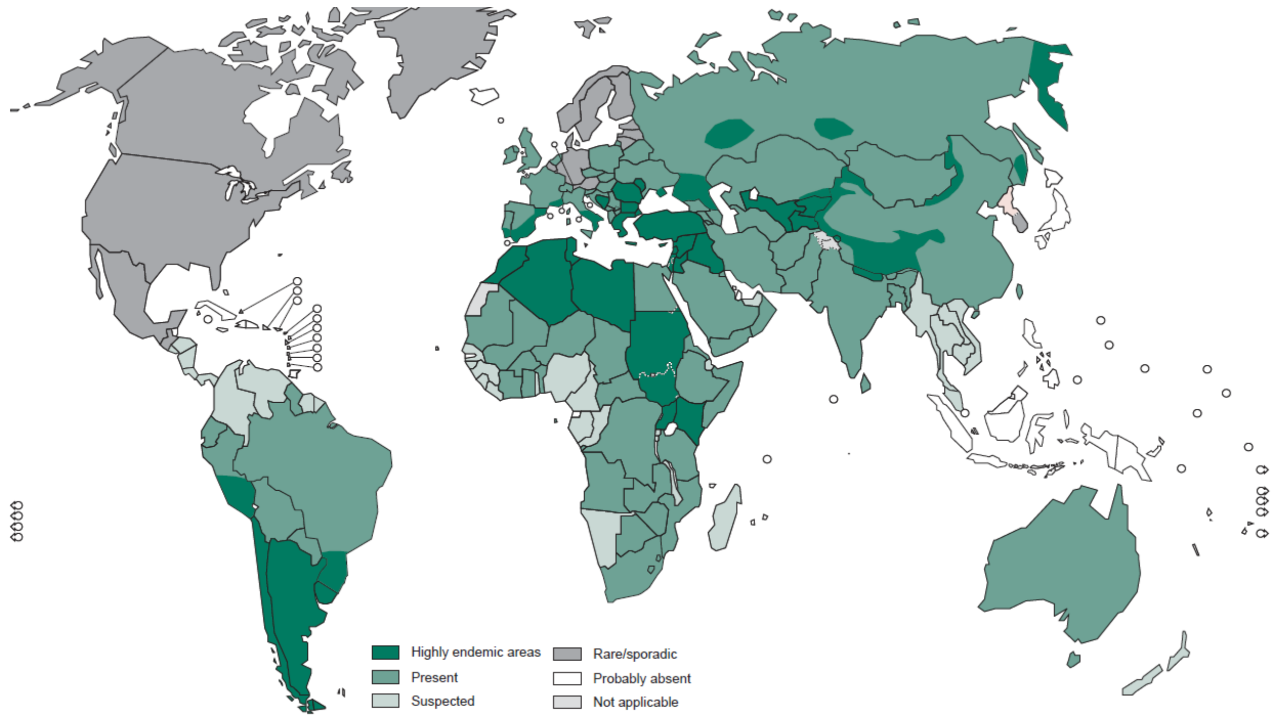


Figure 2: Distribution of Echinococcus granulosus and cystic echinococcosis worldwide, 2012. Source: Third WHO report on neglected tropical diseases. Investing to overcome the global impact of neglected tropical diseases, 2015

There are two main sources, OIE and AU-IBAR (which includes only Africa), but data are not always similar.

1- Source: OIE.

Data of outbreaks reported to the World Animal Health Organization (OIE) are shown in Tables 1 and 2. Data are not always reliable, as many countries doesn't seem to report, or to be reporting consistently over time.

http://www.oie.int/wahis_2/public/wahid.php/Diseaseinformation/statusdetail

Similar information but presented in a different manner can be seen in Annex 1.

Number of cases reported to the OIE by disease and by country:

- No information, + Present but quantitative data not known, ? Disease suspected

Table 1: ASIA – Echinococcosis/hydatidosis outbreaks (2005-2013) and Infection with Echinococcus granulosus (2014) notified to OIE from the Asian countries of interest.

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bangladesh	-	-	+	+	+	+	+	+	+	+	-
India	-	-	-	-	-	-	-	-	-	-	-
Indonesia	0	0	-	0	-	-	-	-	-	-	-
Myanmar	0	1	-	-	2	8	2	3	3	1	-
Nepal	0	0	0	0	0	48	+	0	0	+	+
Vietnam	0	-	-	-	-	-	-	-	-	-	-

Table 2: AFRICA – Echinococcosis/hydatidosis outbreaks (2005-2013) and Infection with Echinococcus granulosus (2014) notified to OIE from the African countries of interest.

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Burkina Faso	-	-	-	-	-	-	-	-	-	-	-
Ethiopia	+?	+?	+?	+?	+?	+?	+?	+?	0	0	-
Ivory Coast	0	0	0	?	0	0	0	0	0	-	-
Kenya	?	?	?	?	?	?	?	?	?	0	-
Madagascar	0	0	0	0	0	0	0	0	0	0	-
Malawi	?	?	?	?	?	?	?	?	?	-	-
Mali	0	0	-	-	+?	-	-	-	-	0	-
Mozambique	+	>1	>1	2	4	2	0	0	+	-	-
Rwanda	-	-	-	0	-	-	-	-	-	-	-
Senegal	-	-	-	-	-	-	-	--	-	-	-

South Africa	0	0	0	0	+?	+?	+?	0	0	0	-
Tanzania	+	+	+	-	+?	+?	+?	+?	+?	-	-
Uganda	-	+	+?	+?	+?	+?	+?	+?	+?	-	-
Zambia	-	-	-	-	0	0	0	0	0	0	-

The OIE, also includes zoonoses data. The number of human cases and deaths are reported by the countries. Data from the countries of interest can be seen in Table 3 below. It is interesting to note that some countries haven't confirmed animal cases (Vietnam, Ethiopia, Kenya, Madagascar, Malawi and South Africa), however they have reported human cases. That only confirms a big level of underreporting.

http://www.oie.int/wahis_2/public/wahid.php/Countryinformation/Zoonoses

Table 3: Human cases and deaths due to Echinococcosis/hydatidosis

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Bangladesh										
India										
Indonesia										
Myanmar										
Nepal						C: +, D: +	C: +, D: +		C: +, D: +	C: +, D: +
Vietnam					C: +, D: +					
Burkina Faso										
Ethiopia	C: +, D: +	C: +, D: +	C: +, D: +	C: +, D: +	C: +, D: +	C: +, D: +		C: +, D: +		
Ivory Coast										
Kenya			C: 5, D: 0	C: +, D: +	C: 3, D: 0	C: +, D: +	C: +, D: +	C: +, D: +	C: +, D: +	
Madagascar								C: +, D: +	C: +, D: +	C: +, D: +
Malawi	C: +, D: +									
Mali										
Mozambique		C: +, D: +				C: +, D: +		C: +, D: +	C: +, D: +	
Rwanda										
Senegal										
South Africa		C: +, D: +	C: +, D: +		C: +, D: +		C: 440	C: +, D: +	C: +, D: +	C: +, D: +
Tanzania	C: +, D: +									
Uganda										
Zambia										

C: Cases, D: Deaths

2- Source: AU-IBAR.

Number of outbreaks per year as reported to AU-IBAR and published in the Pan African Animal Resources Year Book. (**http://www.au-ibar.org/pan-african-animal-resources-yearbook?showall=&limitstart**=)

Table 4 shows the number of Echinococcosis/hydatid outbreaks reported to AU-IBAR. The information is the total reported, and there is no breakdown per country.

Table 4: Number of Echinococcosis/hydatid outbreaks per year as reported to AU-IBAR and published in the Pan African Animal Resources Year Book.

	2009	2010	2011	2012	2013	2014
# Countries affected		3	4	4	2	3
# Outbreaks	85	27	47	141	128	90
# Cases	2,809	497	2,443	2,365	876	488
# Deaths	209	122	161	428	0	2,786
# destroyed / slaughtered	3,349	0	2,617	2,436	3,149	3

Prevalence data by country

- Sources: PubMed, and internet engine searches (English and French when applicable).
- Conference abstracts:
  a. The XXVI World Congress on Echinococcosis, 2015, Bucharest, Romania
  b. XXV World Congress on Echinococcosis, 2013, Sudan.
  c. XXIV World Congress of Hydatidology, 2011, Urumqi, China.
- Efforts have been made to include the year of the study, and not the year of the publication. If they are known to be different, the year of publication is included in the reference.
- Note that not all papers have been read in full. In many cases, only the abstracts have been read. Critical evaluation of the papers for inclusion has not been conducted

ASIA

Bangladesh

- Animals:

Year	Area	Species of animal	No. samples tested	% positive	Reference
2012	Chittagong	Cattle and buffaloes (only lungs were observed)	Cattle: 660 Buffaloes: 222	Cattle: 9.2 Buffaloes: 3.6 Total: 7.82	Islam et al, 2015
2009-2010	Dinajpur	Slaughtered cattle		25.67	Basak et al, 2011
2008		Cattle, buffaloes, Goats and sheep	Cattle: 1460 Buffaloes: 620 Goat: 970 Sheep: 460 Total: 3510	Cattle: 29.65 Buffalo: 9.19 Goats: 35.58 Sheep: 16.95 Total: 26.01	Kabir et al, 2010
2007	Barisal	Buffaloes	80	2.5	Ahmedullah, 2007
2003	Cox's Bazar	Sheep, buffaloes, Cattle and goats		Sheep: 52.11, Buffaloes: 36.11, Cattle: 30.62, Goats: 14.73	Islam, 2003
1982	Mymensingh	Buffaloes	439	42.36	Islam, 1982 a
1982		Slaughtered cattle	10,362	42.15	Islam, 1982 b
1980		Goats	12,344	8.29	Islam, 1980

- Humans:

Data in humans, is usually about case descriptions, and usually about sites where CE occurs rarely. They are listed as evidence of the presence of the disease.

Year	Area	Remarks	Reference
2012		Hepatic cyst	Islam, 2012
2012		Spinal hydatid cyst	Chowdhury, 2012
2002-2011	Referral hospitals in Dhaka	Hospital base study that concludes that there is active transmission of *E. granulosus*. See Figure 3	Karim, 2015
2010		Cranial hydatid abscess	Zahed, 2010
2009	Sirajganj	Cyst of spleen	Bhuiyan, 2009

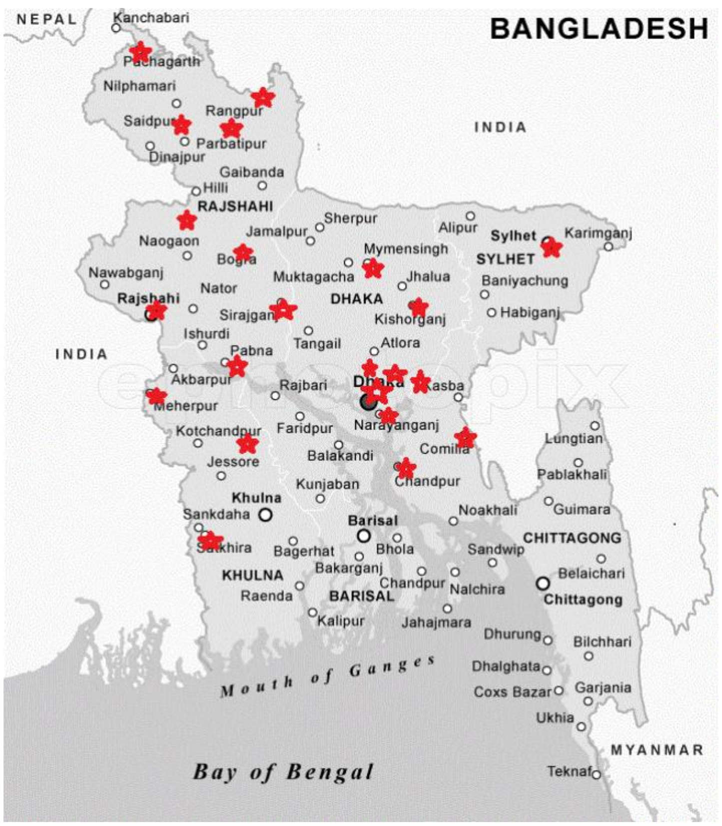


Figure 3: Reported cases of CE (humans) in Bangladesh. Source: Karim 2015

India

- Animals:

Year	Area	Species of animal	No. of samples tested	% positive	Reference
2014	Slaughterhouses in North India	Cattle, buffaloes, sheep, goats and pigs	Cattle: 278 Buffaloes: 298 Sheep: 760 Goats: 2,439 Pigs: 355	Cattle: 5.39 Buffaloes: 4.36 Pigs: 3.09 Sheep: 2.23 Goat: 0.41	Singh et al, 2014
2007-2008	Deonar abattoir (Mumbai)	Cattle, buffaloes, sheep and pigs	Cattle: 824 Buffaloes: 1,050 Sheep: 16,099 Pigs: 3,888	Cattle: 5.10 Buffaloes: 3.81 Sheep: 0.075 Pigs: 0.87	Pednekar et al, 2009 [23]
1989	Aligarh	Buffaloes, camels, sheep, goats and pigs	Buffaloes: 1,556 Goats: 1,208 Pigs: 559 Sheep: 109	Buffaloes: 36 Goats: 2 Pigs: 1 Sheep: 6 Camels: 2 out of 3	Irshadulla, 1989
1988	Northern India		Buffaloes: 754 Sheep: 1,215 Goats: 447	Buffaloes: 48.1 Sheep: 30.5 Goats: 21.0	Singh et al, 1988 a
1988	Bareillly abattoir	Buffaloes	3,200	28.6	Singh et al, 1988 b

Summary of published literature on the prevalence of hydatid disease in livestock (expressed as a range) in different geographical locations in India; Source: Pednekar et al, 2009 [23]. For the original references, please refer to the Pednekar et al paper.

Region	Host	Prevalence (%)		
		1980–1990	1991–2000	2001 onwards
North	Cattle	7.8	21.9	Information not available
	Buffalo	11.3–48.1	18.39	Information not available
	Sheep	4.7–30.5	2.56–7.2	Information not available
	Pig	1–11.25	0.73–1.42	Information not available
South	Cattle	1.7–42.12	6.37–11.85	14.8
	Buffalo	4.0–22	7.24–9.8	7.3
	Sheep	2.5–9.7	3.7–47.6	8.92
	Pig	0.0	3.02–6.89	Information not available
East	Cattle	17.8–31.9	13.3–45	16.76–21.43
	Buffalo	42.25	27.6–48	6.52
	Sheep	8.3–50	9.0	Information not available
	Pig	7.6	1.79–8.0	0.34–0.43
West	Cattle	4.2–21.6	4.16–21.8	13.17
	Buffalo	Information not available	4.6	34.5
	Sheep	Information not available	0.2	0.85
	Pig	Information not available	0.21	3.14–5.58

- Humans:

CE is endemic in India; with highest prevalence in Andhra Pradesh and Tamil Nadu. In India, the annual incidence of human CE per 105 persons varies from 1 to 200 [24].

There has been an increase in seropositive cases of echinococcosis from 10.97% in 1984-1998 to 23.12% in 1999-2003; Casoni's test revealed a similar increase in cases, from 21.38% to 33.83% during the same period in northern India. The highest prevalence of human hydatid disease in India has been reported from Andhra Pradesh, Saurashtra, and Tamil Nadu [25]

There are numerous reports of cases in India, as per following link:

http://www.ncbi.nlm.nih.gov/pubmed/?term=Hydatid+India

Indonesia

There is very limited information. There is a publication from **Margono S, in 2004**. It says that before 1988, hydatidosis were reported from non-indigenous individuals. In 1988 two indigenous, autochthonous human cases were diagnosed as suffering from hydatidosis by clinical and radiological observations, whereas the 3rd case in 1997 was confirmed by anamnesis, clinical, radiological and microscopically examinations. These 3 cases were inhabitants of Sulawesi, one of the 5 biggest islands of the archipelago of Indonesia where adult *E. granulosus* was found in dogs. These findings should alert on the possibility of finding human cases not only in Sulawesi, but also in other regions of the country, especially in regions were the parasite was already found in several animals.

Myanmar

No information was found.

Nepal

- Animals:

A systematic review was conducted by Devleesschauwer et al [26] in 2014 and it concluded that CE is probably endemic in Nepal. It mentioned that CE has traditionally mostly been studied in livestock. The few data in dogs indicate higher prevalence in areas where livestock is slaughtered. Since the 2000s, various case reports have been published on human hydatidosis. Hospital register studies for CE cases have found low incidences. So far, genotyping studies have revealed the presence of G1, the sheep strain in humans, dogs and livestock, G5 (cattle strain) in livestock and G6 (camel strain) in humans.

Year	Area	Species of animal	No. of samples tested	% positive	Reference
2004-2005	Kathmandu Valley	Buffaloes	500	10.6	**Manandhar et al, 2006**
1991	Abattoirs in Kathmandu	Buffaloes, goats, sheep ang pigs	Water buffaloes: 3,065 Goats: 1,783 Sheep: 150 Pigs: 143	W buffaloes: 5 Goats: 3 Sheep: 8 Pigs: 7	**Joshi et al, 2000**

- Humans:

There are several reports of cases in humans. Below are some examples.

Rauniyar et al, 2012: Unusual presentation of an isolated extra hepatic hydatid cyst in the paraspinal muscle.

Joshi A, Shrestha K and Shah LL, 2011: Report on three cases of infected and complicated liver hydatid cysts.

Vietnam

No information was found.

AFRICA

There is a very good 2012 review by Wahlers et al [27], of CE in sub-Saharan African. The specific country information for the countries of interest, has been included under each country. Figure 4 below, shows an overview of the availability and nature of reported epidemiological data on CE as discussed in the paper.

http://www.thelancet.com/pdfs/journals/laninf/PIIS1473-3099(12)70155-X.pdf

CE is regarded as endemic in sub-Saharan Africa; however, for most countries only scarce data, if any, exist. For most of the continent, information about burden of disease is not available; neither are data for the animal hosts involved in the lifecycle of the parasite. Available evidence suggests that several species or strains within the *E. granulosus* complex are prevalent in sub-Saharan Africa and that these strains might be associated with varying virulence and host preference.

CE is highly endemic among the nomadic pastoral tribes of East Africa, but is rare amongst the agriculturally based communities [28]. *E. granulosus* infections are common in dogs from all countries in sub-Saharan Africa where they have been examined. Sheep and goats appear to be the most common domestic intermediate hosts, but recent studies suggest that camels are equally important intermediate host, especially in Sudan and Turkana. At least five of ten *E. granulosus* genotypes are infective to humans in sub-Saharan African. Most human cases of CE are caused by the sheep strain (G1) and camel strain (G6) of *E. granulosus*.

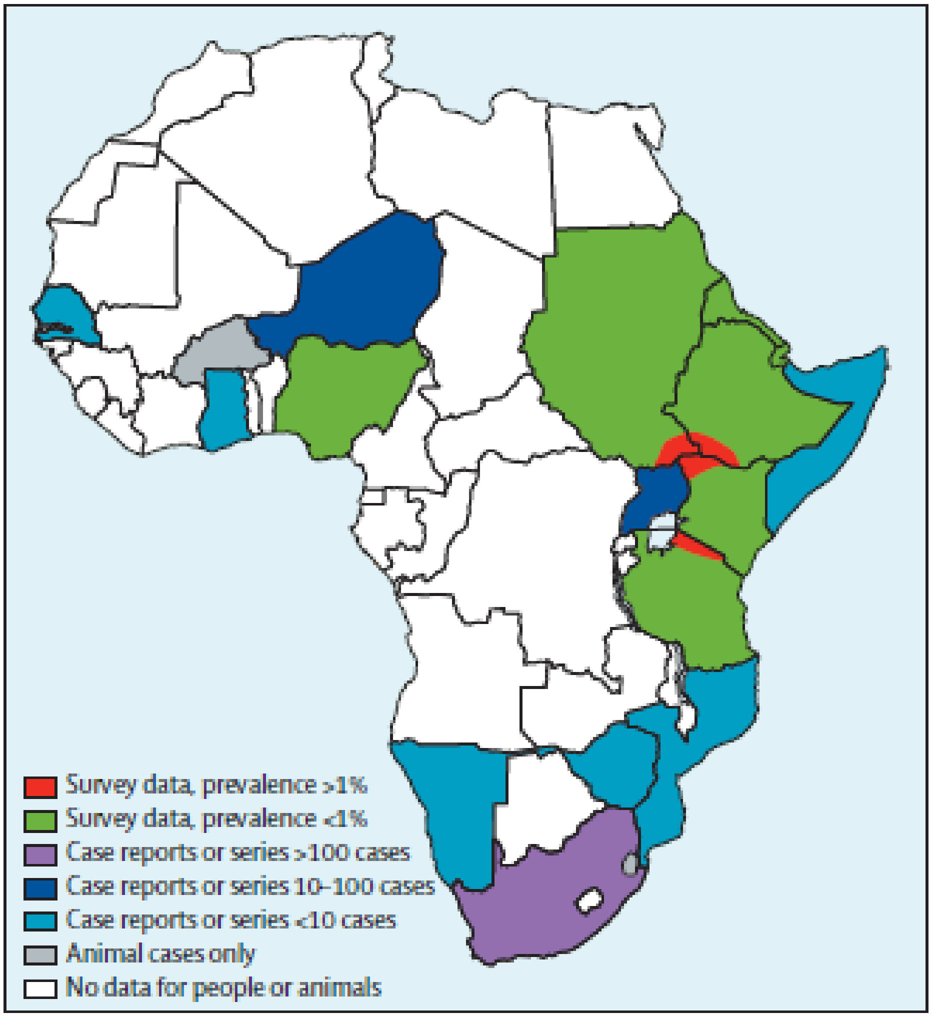


Figure 4: Availability and nature of the reported epidemiological data on CE. Source: Wahlers et al, 2012. The prevalences and numbers refer to human cases, unless otherwise specified.

Burkina Faso

- CE is generally thought to be uncommon in West Africa. In a retrospective survey of CE in Burkina Faso, hydatid cysts were found in 10 of about a million animals of various species (original text refers to a WHO informal working group as source). No data for human disease are available, but it is unlikely to be a major concern in Burkina Faso [27].

- In a study done in the village of Tougori in 2011, 42 samples tested were negative for *E. granulosus* by ELISA and Western Blot. **http://www.jidc.org/index.php/journal/article/viewFile/24820474/1074**

Ethiopia

- Livestock:

The situation in Ethiopia is very well described by Wahlers et al, 2012 [27]: Several researchers have investigated CE in cattle in several parts of Ethiopia, finding regional differences in prevalence and fertility of cysts. The highest prevalences were recorded in central Ethiopia with up to 52·7% of 632 cattle being infected with *Echinococcus* spp (26·9% of cysts were fertile). The highest prevalence of fertile cysts was recorded in eastern Ethiopia, where 32% of cysts were fertile. The lowest prevalences were recorded in southern parts of central Ethiopia, where 16% of 400 cattle were infected (1·8% fertile cysts). Kebede and colleagues argued that in northern Ethiopia, sheep might be the main intermediate host for cystic echinococcosis because they recorded that 10·6% of 380 sheep were infected, with 56·6% of cysts being fertile. By contrast with these findings, Bekele and colleagues did not deem sheep to be the main intermediate host in central Ethiopia, where 16·4% of 560 tested positive but only 18·3% of cysts were fertile. In goats, low prevalence was recorded in central Ethiopia (6·7% of 208),60 whereas Sissay and colleagues noted that 65% of 632 goats examined in eastern Ethiopia were infected. Kebede and colleagues also investigated dogs for infection with *Echinococcus* spp in northern Ethiopia where 3 of 18 of eight dogs were infected. In this area, few human cases of cystic echinococcosis were identified. In eastern Ethiopia, Mersie and colleagues showed that two of nine dogs were infected with *Echinococcus* spp. In central Ethiopia, mainly *E granulosus* G1 has been identified in livestock, whereas in northern Ethiopia (the city of Makale) *E granulosus* G1, *E ortleppi,* and *E canadensis* G6 and G7 were identified in 21 cysts from cattle. In a study from central and eastern Ethiopia, *E granulosus* G1 predominated, but *E canadensis* G6 was also identified, mainly in camels.

Note: there are more publications as can be seen in the following link: **http://www.ncbi.nlm.nih.gov/pubmed/?term=Hydatid+Ethiopia**. Not all have been included, as they are quite similar in information.

Year	Area	Species of animal	No. of samples tested	% positive	Reference
2013-2014	Nekemte abattoir, Western Ethiopia	Cattle	473	17.34	Moje 2014
2013	Adama municipal abattoir, Central Oromia	Cattle	422	27.5	Birhanu 2014
2012-2013	Adigrat	Cattle	360	18.61	Assefa, 2014

2011-2012	Addis Ababa abattoir	Sheep and goats	Sheep: 262 Goats: 250	Sheep: 8.02 Goats: 6.8	**Assefa, 2015**
2010-2012	Akaki abattoir	Camels	770	61.6	**Boru et al, 2013**
2010-2011	Jijiga abattoir, Somali Regional State	Camels	400	23	**Debela, 2015**
2010-2011	Abergelle slaughterhouse	Sheep	1,152	11.6	**Desta et al, 2012**
2009-2010	Addis Ababa Abattoir	Cattle	484	40.5	**Terefe et al, 2012**
2009-2010	Modjo Modern abattoir	Sheep and goats	Sheep: 348 Goats: 767	Sheep: 8.05 Goats: 8.99	**Abiyot et al, 2011**
2009-2010	Modjo Luna Slaughterhouse	Sheep and goats	Sheep: 325 Goats: 440	Sheep: 7.7 Goats: 6.13	**Getachew, 2012**
2008-2009	Hawassa Municipal abattoir	Cattle	632	52.69	**Regassa et al, 2010**
2008	Tigray, North Ethiopia slaughterhouses	Cattle	5,194	22.1	**Kebede, 2009**
2007-2008	Near Kombolcha town, South Wollo	Cattle and sheep	Cattle: 312 Sheep: 197	Cattle: 17.95 Sheep: 7.61	**Degefu, 2013**
2007-2008	Adama abattoir, Central Oromia	Cattle, sheep and goats	Cattle: 852 Sheep: 92 Goats: 208	Cattle: 46.8 Sheep: 29.3 Goats: 6.7	**Getaw, 2010**
1997-2007	Adama abattoir, Central Oromia (Retrospective study)	Cattle	107,333	See Table below	**Getaw 2010**

Retrospective data on cattle hydatidosis at Adama abattoir (1997-2007) Source: **Getaw 2010**

Year	No.	Positive (%)
1997/1998	8,517	1,691.8 (19.9)
1998/1999	8,519	1,326.0 (15.6)
1999/2000	9,101	2,590.1 (28.5)
2000/2001	9,225	2,274.6 (24.7)
2001/2002	10,925	2,730.3 (25.0)
2002/2003	9,518	2,349.0 (24.7)
2003/2004	12,507	3,141.1 (25.1)
2004/2005	12,611	4,201.3 (33.3)
2005/2006	13,240	3,097.7 (23.4)
2006/2007	13,170	2,678.4 (20.3)
Total	107,333	26,080.3 (24.3)

- Humans:
  - **Assefa 2015**: A retrospective analysis covering five years of case reports at two major hospitals in Addis Ababa between January 2008 and December 2012 showed that of the total of 25,840 patients admitted for ultrasound examination, 27 CE cases were registered, a prevalence of 0.1% and mean annual incidence rate of approximately 0.18 cases per 100,000 population.
  - Described by Wahlers et al, 2012 [27]: In Ethiopia, before the introduction of ultrasonography and modern serological tests as routine diagnostic instruments, Fuller and Fuller showed that the Dassanetch and Nyangatom people from the southwest of the country had a prevalence of CE of up to 5% on the basis of findings of clinical examination, and more than 5% when the hydatid skin test was taken into consideration. The Dassanetch and Nyangatom peoples live in the same geographic area as the Turkana people of northwest Kenya, and these populations seem to share customs because they all use dogs for cleaning purposes. By contrast, results of an ultrasound survey of the Hamar people of southwestern Ethiopia showed a much lower prevalence (0.7% of 990 people) than for the Dassanetch and Nyangatom peoples. Macpherson and colleagues did ultrasound surveys of various ethnic groups in southern Ethiopia and recorded the highest prevalence in the Nyangatom people (2.9% of 1334). Case series have been reported from central Ethiopia. Between 72 and 234 patients were seen over 10–15 years at hospitals in Addis Ababa. By contrast with other countries, researchers did not identify a female predominance in these case series and cases of CE in lung and liver seemed to be much the same, at about 40%.

Ivory Coast

The disease is rare in West Africa. Schmidt published in 1978 the first reports of human cases in Ivory Coast. **http://www.ncbi.nlm.nih.gov/pubmed/217550**.

A fourth case was reported in 1982. **http://www.ncbi.nlm.nih.gov/pubmed/6293728**. However, no more recent publications are available.

Kenya

The situation in Kenya, has been well summarized by Wahlers et al, 2012 [27]: CE occurs in most parts of the country but available data are mostly from Turkana communities in the northwest and from Maasai communities in the south. Both communities are nomadic pastoralists rearing huge herds of livestock (sheep and goats, cattle, donkeys, and in the Turkana also camels).

Turkana area: In one serological survey, prevalence of CE was as high as 16.4% in recently settled communities in the Turkana area. Results of another serological survey showed regional differences within the Turkana district, with a prevalence of 9.4% in north Turkana and 2.1% in south Turkana, which was much the same as in a control group from other parts of Kenya.

Ultrasonography is the most commonly used and most reliable diagnostic technique for surveys. In such surveys, the prevalence of CE in the Turkana district was 5.6%. Irvin reported that 4.5% of 791 surgical procedures in one hospital were for CE. In clinical cases, a predominance of women has been noted, with women of child-bearing age having the highest prevalence. Because most rural hospitals do not have radiograph facilities, lung disease is likely to be underdiagnosed.

A domestic lifecycle of *Echinococcus* spp with dogs as the definitive host and small ruminants, cattle, and camels as intermediate hosts was thought to be most important in the Turkana district. An independent wildlife cycle has not been described. Several studies in livestock (ultrasound surveys and abattoir surveys) have been done in Turkana. Prevalences of CE varied significantly within Turkana, but generally camels and cattle showed the highest prevalences (cattle 19%, camels 61%).

Maasai area: By contrast with Turkana district, much lower prevalences of CE have been identified in the Maasai area of southern Kenya (0.5%, Zeyhle E, unpublished). Despite high infection rates in their livestock and dogs and a favourable climate for the survival of echinococcal eggs in the environment, infection in people was much lower than in Turkana (0.5% *vs* 2.5% in 2010, Zeyhle E, unpublished). As in Turkana, sheep and goats seemed to be the most important intermediate hosts, but by contrast with the Turkana area an additional wildlife cycle probably exists. Although Maasai lead a lifestyle that is much the same as that of the Turkana, they have more water available to them for daily living and they do not rely on dogs for cleaning purposes, therefore their dog–man contact is less close.

Isolates: Many *Echinococcus* spp isolates from Kenya have been examined genetically, mainly belonging to *E granulosus* G1 (sheep, goats, cattle, camels, pigs, people, and dogs) and *E canadensis* G6 and G7 (camels, cattle, goats, people, and dogs), and only one to *E ortleppi* (pig). Most samples originated from the northwest of the country (Turkana). In the Turkana district, the sheep strain is the predominant taxon in people, sheep, cattle, and goats, whereas the camel strain predominates in camels and partly in goats. Only two isolates of 176 hydatid cyst specimens isolated from people were identified as the camel strain (G6) whereas all remaining isolates belonged to the sheep strain (G1).

However, more recent publications, mention an increase of prevalence in the Maasi area (Addy 2012 [29]). The table below shows additional information to the one described by Wahlers

Year	Area	Species	No. of samples tested	% positive	Reference
2014	Central to Northeastern Kenya (no Turkana or Maasai areas)	Cattle, camels, goats and sheep	Cattle: 4,595 Camels: 216 Goats: 2,955 Sheep: 65	Cattle: 1.92 Camels: 6.94 Goats: 0.37 Sheep: 4.62	**Mbaya et al, 2014**
2012	Maasailand	Cattle, sheep and goats	Cattle: 587 Sheep: 430 Goats: 194	Cattle: 25.8 Sheep: 16.5 Goats: 10.8	**Addy et al, 2012a**
2012	Turkana	Cattle and goats	Cattle: 97 Goats: 73	Cattle: 12.4 Goats: 6.8	**Addy et al, 2012 b**
2009-2010	Maasai Mara	Cattle, goats, sheep. Humans	Cattle: 873 Sheep: 504 Goats: 376 Humans: 851	Cattle: 16.4 Sheep: 15.7 Goats: 11.4 Humans: 0.5	Magambo, 2011*

* Magambo 2011: Proceedings Hydatidology Congress Urumqui, 2011. Page 48.

- Humans:
    - Although G1 is the E*. granulosus* genotype most commonly involved in CE in humans, infections with G6 (camel strain) might be higher than initially thought. A study done in 1993-1994 in Turkana district, showed that out of 59 isolates, 83% were G1, and 17% were G6. (**Casulli 2010**)
  - A more recent publication by **Mutwiri et al in 2013** analysed 80 samples from 26 subjects, and found 85% to be *E. granulosus s s* (G1-G3), and 15% *E. canadensis* (G6/7).

Madagascar

Four human cases were reported in Madagascar in 1994 (**http://www.ncbi.nlm.nih.gov/pubmed/7575029**). No more publications were found, despite human cases being reported to the OIE in 2012, 2013 and 2014.

Malawi

No information has been found.

Mali

The disease is rare in West Africa, but it has been reported in Niger-Mali-Mauritania, where the camel is the main intermediate host (**Aubry, 2013**).

Human cases have been reported but the publications are mainly surgical descriptions. Some examples: **http://www.malimedical.org/2005/3p34.pdf**, **http://www.em-consulte.com/es/article/8589/la-chirurgie-du-kyste-hydatique-pulmonaire-au-mali**,.

Mozambique

Despite being animal and human cases reported to the OIE, the information is very limited.

In a study of HIV-1 infected people in Beira in 2014, out of 601 patients, 17.3% were seropositive for echinococcosis. (**http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0003121**)

Rwanda

No information available. Disease never reported to OIE.

Senegal

Cases of human echinococcosis have been reported from Senegal but the reports are from 1970s and 1989. No recent publications have been found.

South Africa

- Livestock:

In 1965, Verster and colleagues investigated the prevalence of CE in livestock at abattoirs nationwide and results are summarised by Wehlers 2012 [27]. Prevalences varied greatly between regions and species investigated. For cattle, prevalences ranged between 1.2% and 13.8%, with the highest in the Eastern Cape and the lowest in the Karoo. However, the investigators also noted that prevalences increased with age in cattle, and therefore differences could be attributable to differences in age of animals slaughtered rather than being true variations in prevalence. For sheep, the prevalence ranged from 0·8% in the Karoo to 2·2% in Mpumalanga. For goats, prevalence ranged from 0% in the Western Province to 3·2% in the Eastern Cape but the numbers of slaughtered animals were small. The dog was regarded as the main definitive host, although infected black-backed jackals were identified in the Eastern Cape and Western Transvaal.

No more recent information has been found.

- Humans:

In the last Hydatidology Congress in Romania (October 2015), Mbae et al, mention in the abstract of “CE in sub-Saharan Africa: new developments” page 20, that in South Africa, hospital data indicate a far larger public health impact of CE than previously assumed, but no more details are provided.

Wahlers in 2011 [30], describes a retrospective data analysis of the National Health Laboratory Service (NHLS) laboratory information system on echinococcosis serology, microscopy and histopathology results in eight provinces (excluding KwaZula-Natal) on human CE in South Africa. Data from 8 of the 9 South African provinces showed that there are a considerable number of cases of CE in South Africa. Even using the most conservative estimation by only considering the strongly positive serology and the microscopic demonstration of *E. granulosus* hooklets, about 137 cases per year should be seen in the 8 provinces covered by the database. The review of cases of CE presenting to hospitals in Johannesburg demonstrates, however, that in many cases, as to be expected – and as underlined by expert critique regarding the meaningfulness of serology in the diagnosis of individual CE cases – serology remains negative, so the true number of patients with CE is likely to be considerably higher.

The same data analysed by Mogoye (**http://www.ojvr.org/index.php/ojvr/article/viewFile/469/537**) showed an overall positivity rate in submitted diagnostic samples of 17.0% (1056/6211). It also became apparent that there might be a regional variability in the prevalence of CE, with the highest rates of positive serology and microscopic demonstration of requested tests from the Eastern and Western Cape provinces, with the Eastern Cape (30.4%), North West (19.0%) and Northern Cape (18.0%) provinces showing highest rates. It has previously been reported that about 20 cases of CE are seen at a single hospital in the Eastern Cape annually (Kayser, 1980).

Mogoye also analysed parasite material collected from patients between August 2010 and September 2012 (**http://www.ncbi.nlm.nih.gov/pubmed/23623184**) and analyzed by PCR/RFLP methods. A total of 32 samples was characterized as *E. granulosus sensu stricto* (G1-G3) (81%), *E. canadensis* (G6/7) (16%) and *E. ortleppi* (G5) (3%).

Tanzania

- Livestock:

Year	Area	Species	No. of samples tested	% positive	Reference
2013	Ngorongoro District	Sheep and goats	180	19.4	**Miran, 2013**
2009	Ngorongoro District	Cattle, goats and sheep	Cattle: 357 Goats: 619 Sheep: 105	Cattle: 48.7 Goats:34.7 Sheep: 63.8	**Ernest et al, 2009**
2005-2007	Arusha. Retrospective study at municipal abattoir	Sheep, goats and cattle	Cattle: 115,186 Sheep and goats: 99,401	Cattle: 4.2 Sheep and goats: 6.02	**Nonga, 2009**
2002-2004	Tanga city abattoir	Cattle	Cattle: 12,444	1.56	**Swai et al, 2012**
1998-2001	Retrospective study 4 years data from 4 slaughter slabs in Ngorongoro.	Cattle, goats and sheep	Cattle: 2,677 Goats: 3,047 Sheep: 607	47.9	**Ernest et al, 2009**
1997-1998	Mbulu	Pigs	70	4.3	**Ngowi et al, 2004**

- Humans:
    - A retrospective study from 1990 to 2003 in Ngorongoro district (**Ernest et al, 2010**) reviewed hospitalization records. A total of 171 hydatidosis patients were diagnosed and operated giving an average of 13 cases per year, equivalent to approximately 10 cases per 100,000 people per year. Women and young people were most commonly affected by cystic echinococcosis. Epidemiological data for human disease from other parts of the country are not available.

- In **1989, Macpherson et al**, undertook an epidemiological study of CE, based on surgical records, in the Maasai people. It showed an annual morbidity of 11 cases per 100,000, with women and children being most commonly operated on. With ultrasound examination, the prevalence of CE was 1.1% in 959 people examined.

Uganda

- Livestock:

Year	Area	Species	No. of samples tested	% positive	Reference
2014	Soroti municipal abattoir (north east)	Goats and sheep	Goats: 294 Sheep: 160	Goats: 33.33 Sheep: 42.5	**Nyero et al, 2015**
2013	Abattoirs in Moroto, Kumi, Luwero and Nakasongola	Cattle, sheep and goats	Not specified. Preliminary data.	Cattle: 2.7 Sheep: 13 Goats: 9	Omadang, 2013
2011-2012	Six districts of Karamoja	Various	Goats: 5,105 Sheep: 4,675 Cattle: 1,006 Donkeys: 612 Camels: 112	Goats: 22.5 Sheep: 28.6 Cattle: 18.7 Donkeys: 0.4 Camels: 0.9	Inangolet, 2013*

Omadang 2013: Abstract 21 “Prevalence and economic impact of echinococcosis in livestock among pastoral and agor-pastoral communities in selected districts of Uganda” in the Proceedings of the XXV Hydatidology Congress in Sudan, November 2013.

Inangolet 2013*: Abstract 29 “The epidemiology and public Health important of Echinococcosis in pastoralist production systems in Karamoja region, Uganda” in the Proceedings of the XXV Hydatidology Congress in Sudan, November 2013.

- Humans:
  - In the last Hydatidology Congress in Romania (October 15), Mbae et al, mention in the abstract of “CE in sub-Saharan Africa: new developments” page 20, that the first country-wide ultrasound surveys for human CE in Uganda reveal high prevalences in all parts of the country but no details are provided.

- Othieno et al, reported in the 2013 Hydatidology Congress in Sudan, Abstract 22, (November 2013), the results of a cross sectional study done in 2012-2013 in pastoral and agro-pastoral areas in Uganda to determine the prevalence of CE in humans by using Ultra sound screening. Surveys were done in the Pastoral districts of: Moroto, Napak Nakapiripirit and Amudat in Karamoja region. While for agropastoral areas studies were done in the Teso region in the districts of Kumi and Bukedea; in Central Uganda, in district of Nakasongola; and in western region in the districts of Kasese and Lwizi. Among 2,849 participants sampled 1.61% (n=64) were positive. All districts screened had positive cases. Nakasongola had the highest number (4.12%) of CE cases. Nakapiripirit had the least number only one case was identified. Generally, more women were affected than men in a ratio of 1:2.07. More cases of CE were found in pastoral areas.

- Hospital records among the Karimojong community and in Western Uganda have shown that on average, 20 surgical cases per year of cystic echinococcosis are reported in each of the hospitals in Karamoja and Mbarara in Western Uganda (Macpherson 2004, referenced in **Inangolet, 2010**).

- There is an old study in humans, from 1975 conducted by **Owor and Bitakarame**. They who reviewed the accumulated cases between 1967-1972. Via the national pathology service 23 cases were identified retrospectively over a period of 6 years. A female predominance was noted. Most cases were imported from Sudan (n=12) and only ten cases occurred in Ugandan people; these people were exclusively from the northern and northeastern districts of the country bordering southern Sudan and northern Kenya (Turkana). In the district closest to Turkana (Karamoja), where five of the ten Ugandan cases originated, 20% of cattle were infected with *Echinococcus spp*. In the two other districts (Acholi and Lango) where human cases were reported, the prevalence in cattle was 1%. In another district (Teso) south of the districts from which human cases were reported, a prevalence of 10.5% in cattle was noted. About two thirds of dogs in the Moroto district were infected with uncharacterised *E granulosus*.

Zambia

- Livestock:

Year	Area	Species	No. of samples tested	% positive	Reference
2007-2008	Two abattoirs in Mongu, Western Province	Cattle	Mongu: 2,441 Senanga: 577 Kalabo: 653 Lukulu: 335	Mongu: 2.5 Senanga: 2.1 Kalabo: 1.4 Lukulu: 0.6	**Banda et al, 2013**

			Shagombo: 47 Kaoma: 8 Total: 4,061	Shagombo: 0 Kaoma: 0 Total: 2.1	
1994-2007	Retrospective study. Data from District Vet Officers and abattoirs	Cattle	158,456	See details by year in Table below.	**Banda et al, 2013**

Annual abattoir prevalence of hydatid cysts based on post-mortem findings in slaughtered cattle Source: **Banda et al, 2013**.

Year	No. of slaughtered cattle (*n*)	No. of positives	Condemned organs	Combined prevalence (%)
1994	3500	144	Lung (142) Liver (2)	4.11 (95% CI: 3.49–4.83)
1995	3973	102	Lung (99) Liver (2) Spleen (1)	2.59 (95% CI: 2.14–3.13)
1996	791	15	Lung (15) Liver (0)	1.90 (95% CI: 1.11–3.19)
1999	30497	1103	Lung (1035) Liver (68)	3.62 (95% CI: 3.41–3.84)
2000	14268	630	Lung (616) Liver (14)	4.42 (95% CI: 4.09–4.77)
2001	2633	123	Lung (121) Liver (2)	4.67 (95% CI: 3.91–5.56)
2003	36124	997	Lung (953) Liver (44)	2.76 (95% CI: 2.59–2.94)
2004	25604	645	Lungs (539) Liver (106)	2.52 (95% CI: 2.33–2.72)
2005	10893	456	Lungs (433) Liver (23)	4.19 (95% CI: 3.83–4.59)
2006	12641	197	Lung (182) Liver (15)	1.55 (95% CI: 1.35–1.78)
2007	17532	277	Lung (246) Liver (31)	1.58 (95% CI: 1.40–1.78)
Total	158,456	4,689		2.96 (95% CI: 2.88–3.04)

- Humans
    - In the last Hydatidology Congress in Romania (2015), Mbae et al, mention in the abstract of “CE in sub-Saharan Africa: new developments” page 20, in Zambia human and livestock CE are moderately frequent in the western part of the country. To date, only the cattle-associated *E. ortleppi* was identified in Zambia.
    - In the same Congress, in a different abstract called “Species, genotypes and life cycles: news out of Africa” by Romig, page 20, it is mentioned that *E. granulosus* s.s. is present in all surveyed countries (Sudan, Ethiopia, Kenya, Uganda, Zambia, Namibia and South Africa) except Zambia. E. ortleppi is

widespread, but sporadic in most regions, more frequent in some traditional cattle-husbandry areas (e.g. western Zambia) and human cases are known, but rare.

- A retrospective review of, records of human CE from Lewanika General Hospital, which is a referral centre for Western Province over a 4 year period (2006 to 2010) was conducted and analysed to determine the prevalence of the parasite in humans. Proportion positive in humans was 0.009 % (9 per 100,000 cases attended to). 67% of the human cases diagnosed were females and 33% male humans. **http://dspace.unza.zm:8080/xmlui/handle/123456789/3088**
- There are reported cases from people that hasn't left the Northern and Lusaka provinces: **http://www.bioline.org.br/pdf?js04029**

Economic and Social Impacts at Global and Regional Levels, and in Selected Countries

The WHO mentions in its Third report on neglected tropical diseases “Investing to overcome the global of impact of neglected tropical diseases” (2015), that in regions where cystic echinococcosis is endemic the incidence in humans can exceed 30/100 000 person-years; prevalences as high as 5–10% may occur in parts of South America, Central Asia, China and Africa. The postoperative death rate for surgical patients is 2.2%; 6.5% of cases relapse after intervention and require prolonged recovery time. Human echinococcosis can be life-threatening if undiagnosed and untreated. Treatment often includes costly surgery.

Odero et al, in an abstract presented at the XXV Hydatidology Congress in Urumqui (China), 2011, page 170, mention that the burden of CE is significant in highly endemic areas. Surgical cyst removal is the main form of treatment and, therefore, human CE represents a serious and costly public health challenge in endemic regions. Recurrences following surgery usually result in higher morbidity and mortality rates. Use of albendazole and percutaneous cyst aspiration provide useful additional treatment of complicated CE at additional cost. Recent estimates for the average cost for surgical treatment of CE in UK was >US$ 10,000, and >US$ 4,000 – 6,700 in Argentina. In addition to public health impacts, economic losses due to condemnation of affected livestock organs are significant.

In addition to public health impacts, economic losses due to condemnation of affected livestock organs are significant. The WHO mentions in “Investing to overcome the global of impact of neglected tropical diseases” (2015), that in livestock, the rate of cystic echinococcosis found in slaughterhouses in hyperendemic areas of Latin America varies from 20% to 95% of slaughtered animals. The highest rates have been found in rural areas where older animals are slaughtered. In Sardinia, Italy, during 2005–2010 in the absence of specific control measures, the prevalence of cystic echinococcosis in sheep was 65%; about 14% of sheep harboured at least one fertile cyst. Livestock production losses attributable to cystic echinococcosis include the liver and lungs being condemned as unfit for consumption, a reduction in the weight of carcasses, a decrease in the value of the animal’s hide, a decrease in milk production and reduced fecundity.

Echinococcosis imposes an economic burden in developing countries. Budke et al. [20] estimate the annual global economic losses due to CE in livestock to be >US$2B.

Analysis by the World Bank:

The World Livestock Disease Atlas – a quantitative analysis of global animal health data [31], published by the World Bank (with cooperation of OIE and FAO) in 2011 is an attempt to understand which livestock diseases cause the heaviest losses, which countries suffers the worst disease-related losses and which livestock species are most affected.

http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/02/17/000356161_20120217030841/Rendered/PDF/668590WP00PUBL00Livestock0Atlas0web.pdf

The World Livestock Disease Atlas bases its analysis on the Livestock Units (LSU). Each species has a LSU value, and the losses of LSU have been given a value. See Figure 5. For more information on the methodology description, please refer to the World Bank Atlas itself (pages 6 & 7). Echinococcosis is one of the top 10 diseases causing losses for cattle, buffalos and small ruminants, as shown in Figure 6. However, looking at the data in detail, there are few data from sub-Saharan Africa and Asia.

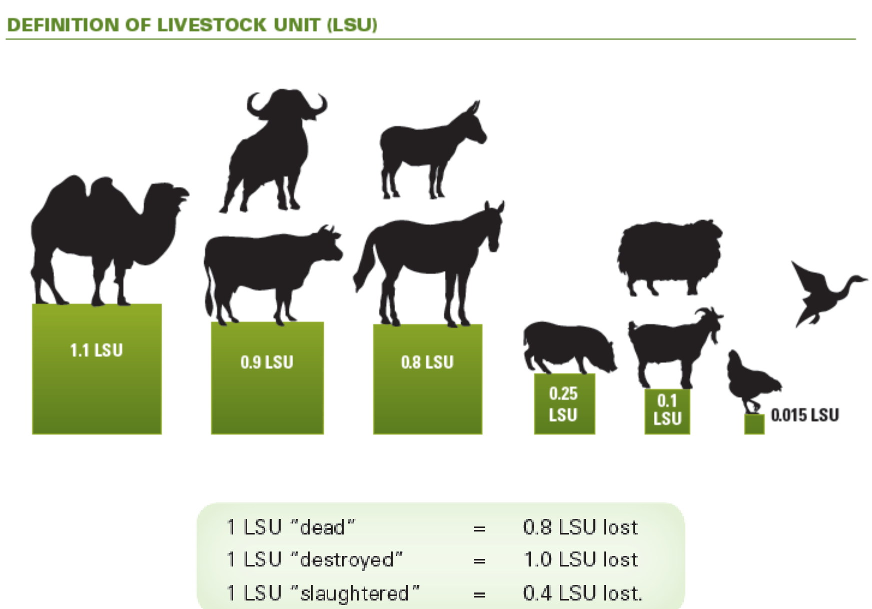


Figure 5: Livestock Units. Source: World Livestock Disease Atlas – The World Bank, 2011 [31].

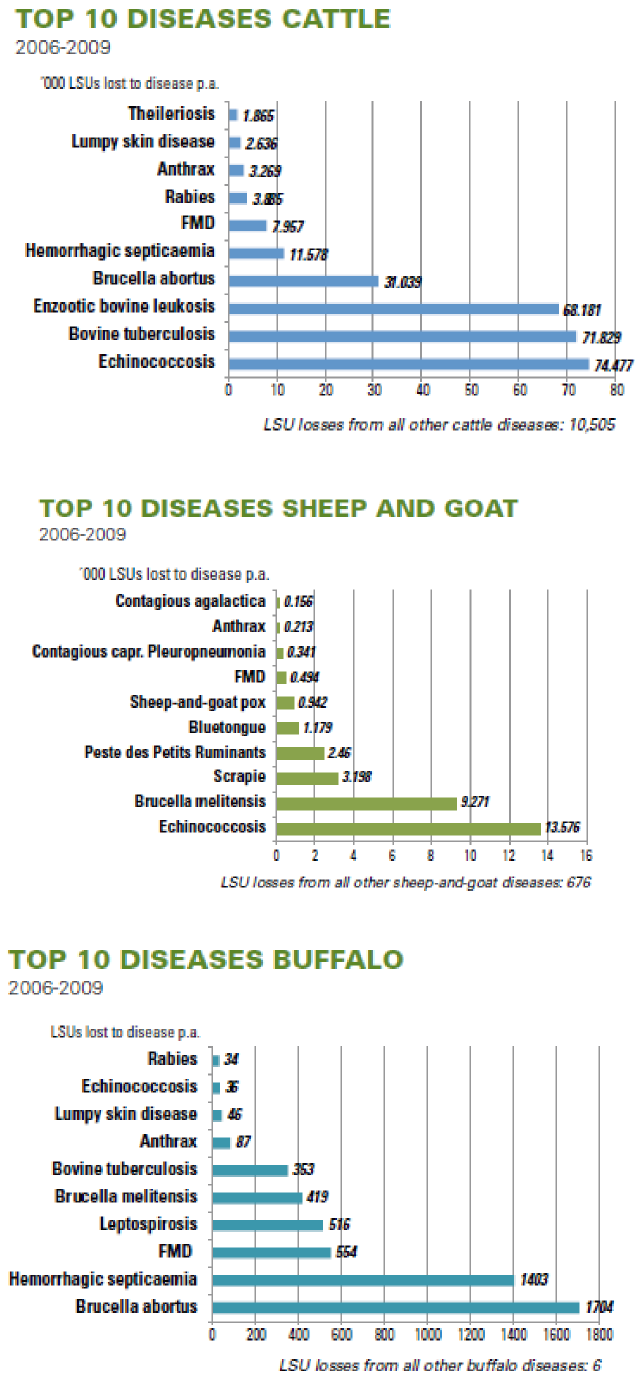


Figure 6: Top 10 diseases in terms of LSU losses for cattle, buffalo, and sheep & goats. Source: World Livestock Disease Atlas – The World Bank, 2011 [31].

Impact on specific focus countries

India

The first systematic analysis of the livestock and human related economic losses due to cystic echinococcosis in India was conducted in 2014 by **Singh et al** [32]. Data about human cases were obtained from a tertiary hospital. Human hydatidosis cases with and without surgical interventions were extrapolated to be 5,647 and 17,075 per year assuming a total human population of 1,210,193,422 in India. Data about prevalence of hydatid cysts in important food producing animals were obtained from previously published abattoir based epidemiological surveys that reported a prevalence of 5.39% in cattle, 4.36% in buffaloes, 3.09% in pigs, 2.23% in sheep and 0.41% in goats. Animal population data were sourced from the latest census conducted by the Department of Animal Husbandry, Dairying and Fisheries, India. Other input parameters were obtained from published scientific literature. Probability distributions were included for many input values to account for variability and uncertainty. Sensitivity analyses were conducted to evaluate the effect of important parameters on the estimated economic losses. The analysis revealed a total annual median loss of Rs. 11.47 billion (approx. US $ 212.35 million). Cattle and buffalo industry accounted for most of the losses: 93.05% and 88.88% of the animal and total losses, respectively. Human hydatidosis related losses were estimated to be Rs. 472.72 million (approx. US $ 8.75 million) but are likely to be an under-estimate due to under-reporting of the disease in the country. The human losses more than quadrupled to Rs. 1953 million i.e. approx. US $ 36.17 million, when the prevalence of human undiagnosed cases was increased to 0.2% in the sensitivity analyses. The social loss and psychological distress were not taken into account for calculating human loss. The results highlight an urgent need for a science based policy to control and manage the disease in the country.

Nepal

Impact on humans: Between 2000 and 2012, the annual burden of cystic echinococcosis was calculated at 251 DALYs (95% Credibility Interval: 105–458) [26].

Ethiopia

Several papers include data about the economic cost of organ condemnation at different abattoirs. Of course the annual losses will depend on the number of animals slaughtered and the prevalence of hydatid (costs are not presented per animal slaughtered). Some examples are given below:

- **Brhane and Abebe, 2015**: The annual financial losses from organ condemnation due to hepato-pulmonary bovine hydatidosis at Jimma municipal abattoir were estimated to be 94,485.60 ETB or 4,972.93USD
- **Regassa 2010**: the total annual economic loss from organ condemnation and carcass weight loss due to bovine hydatidosis at Hawassa Municipal abattoir was estimated at 1,791,625.89 Ethiopian Birr (USD 138,563).
- **Kebede and colleagues** estimated the total annual loss from bovine hydatidosis due to offal condemnation (lung and liver) and carcass weight loss in the study areas to be 25, 608 Eth. Birr (2,807 USD) – Tigray region. They suggested that the actual loss was even greater because home slaughtering practices were common.

Kenya

As per a report by Odero et al in an abstract presented at the XXV Hydatidology Congress in Urumqui (China, 2011, page 170):

Human infection data for Kenya was obtained from the AMREF database, and livestock data were collected from various slaughterhouses in Kenya. In this on-going study, retrospective and prospective data on human infection and prevalence in livestock was used to estimate disability-adjusted life years (DALYs) for Kenya and calculate the economic losses due hydatid disease infection in livestock.

Results: From the data analyzed so far, we calculated the average cost to US$ 610 per case for diagnosis and treatment (surgery/PAIR) at Kakuma Mission Hospital (Turkana District), where most of cases were operated. Economic losses in livestock, production-based losses are significant.

Disease Prevention and Control Methods

Because humans infected with CE pose no risk to other humans, all efforts to control transmission of the disease must be implemented either towards reducing the exposure of humans to the parasite (sanitation, exposure to infected dogs) or intervention measures directed towards the animal hosts. Considerable efforts have been made in many countries to reduce the transmission of *E. granulosus* with a view to reducing the incidence of human CE. The first disease control program for CE was instigated in Iceland in 1863 following the realization that a high proportion of the human population suffered from the disease. Some remarkable characteristics of the social situation in Iceland at the time facilitated an extremely successful disease control program based mainly on public education [33]. CE was recognized as an important concern for human health in other parts of the world; for example a national commission of experts was appointed in Argentina in 1906 which elaborated a report on measures that should be adopted to prevent transmission of the parasite [34]. However, it was not for nearly a century after the initiation of control activities in Iceland and promulgation of evidence of the success of the Icelandic campaign that concern for the burden of human CE in other countries led to the establishment of concerted control efforts elsewhere. New Zealand was the first country to instigate serious CE control activities in the 20th century. Shortly after a formal hydatid control campaign began in New Zealand in 1959, a voluntary education campaign to control CE disease was established in Tasmania, Australia, which subsequently expanded into a formal government-funded program in 1965 [33]. Since that time the United Nation agencies, the Food and Agriculture Organization (FAO), Pan American Health Organization (PAHO), World Health Organization (WHO), United Nations Environment Program (UNEP) and the Office International des Epizooties (OIE) undertook a series of workshops and other activities concerning echinococcosis [35]. Subsequently, new CE control activities were initiated in many countries of the world [36] and the current WHO/OIE guidelines were prepared concerning the surveillance, prevention and control of echinococcosis [3]. The disease control activities in different countries have varied enormously in their effectiveness, with some leading to the complete elimination of the disease while others have failed almost completely to have any impact.

Dr Michael Gemmell prescribed various options and decision making processes that provide a rational basis for undertaking control activities (Gemmell 1987; Gemmell 1995 [42]; Gemmell et al. 1986a, 1987; Gemmell and Roberts 1998 (43); Gemmell et al. 2001 – all referenced in Lightowlers 2012 [41]). This theoretical basis became an integral part of the 2001 update to the WHO/OIE Guidelines on echinococcosis and remains recognized to this time [13].

During the latter half of the 20th century many separate activities were commenced with the aim being to reduce the prevalence of CE in humans. Those that were successful have tended to be reviewed comprehensively in publications while those that were less successful have often not been the subject of detailed publications that could provide information about why those control activities were not successful [36][38]. A comprehensive reference to CE control activities around the world can be found in the report of a PAHO/WHO Working Group meeting held in San Carlos de Bariloche, Argentina, during September 1999 [36]. In spite of efforts to control transmission of *E. granulosus* in many parts of the world, the disease remains prevalent in humans throughout many regions of the world. There remains an urgent need for new echinococcosis control activities and the implementation of improved methods for controlling transmission of the disease.

The various control campaigns that have been undertaken to date have employed a wide variety and combination of measures and, because each country has presented unique political and social circumstances, it is difficult to prescribe universal measures for all situations. Constraints on which particular control measures are applicable in different regions and countries can have great impacts on the effectiveness of the control efforts. For example, stray dogs pose a serious problem for CE transmission. They predate hosts such as sheep and goats and they are near impossible to include in an anthelmintic dosing regimen. The political and social situation in Sardinia prevented stray dogs from being euthanized as part of CE control measures implemented in the 1990's; rather they were required to be maintained, for life, in pounds. In stark comparison, the problem with stray dogs was solved in Cyprus with the euthanasia, mostly by shooting, of 82,984 dogs [39]. In the year 1971 alone, 27,552 dogs were destroyed, equating to 75 dogs every day. Social and farming practices also have major influences. For example, in Sardinia the sheep are used almost exclusively for milking. The old animals have little meat value and very few are sent to abattoirs for slaughter. Rather, they are either slaughtered on-farm with the hydatid infected offal discarded, or they simply die in the fields [40]. Although it is difficult to draw general conclusions from examining the effectiveness of CE control measures in different countries, consideration of the successes and failures does provide some clues as to which control activities may be of value for future CE control initiatives. Lightowlers [41] examined selected examples of campaigns that led to complete eradication of the disease as well as an example where initial efforts failed but where more recent changes to the control measures have led to success. Also, Gemmell and his colleagues have compared and contrasted the CE control programs undertaken around the world, highlighting features that have favored either success or failure. Voluntary public education measures appear to have been almost universally ineffective in bringing about a substantial decrease in disease transmission. The exception is Iceland where some extraordinary circumstances there led to education being effective. After praziquantel became available as a highly effective taeniacide for dogs, it became incorporated as an integral component of all active CE control programs. However, its frequency of use and whether it is delivered by control program staff or the dog owners themselves have significant impacts on the effectiveness of the drug for controlling disease transmission. Gemmell [42] and Gemmell and Roberts [43] highlight the surety of on-going funding for control programs as being a vitally important factor in the likelihood that CE control will be effective. Where funding has been adequate, dog treatments have been undertaken by trained staff of the control program (eg New Zealand and Tasmania, Wales 1983-9). Where insufficient funds have been available, taeniacides have been distributed to dog owners or dog owners have been expected to purchase the treatments themselves, leading to problems with compliance.

A vaccine has been developed which can greatly reduce transmission of *E. granulosus* by livestock animals. This vaccine provides a valuable new tool for CE control and its origin and role are discussed further below.

Treatment (Control)

In humans, treatment with benzimidazole drugs, principally albendazole, forms an important aspect of disease management. However, to be effective the drugs are required to be given in large amounts over long periods of time. No practical treatment has been developed for livestock animals. Dogs infected with Echinococcus spp. can be treated with a single dose of praziquantel. The treatment is virtually 100% effective and, to date, it has formed the mainstay of CE control program worldwide. However, there is no effective immunity in dogs to re-infection with Echinococcus. In the absence of effective control measures being implemented in the intermediate hosts, unless the drug is applied as intervals of 6 weeks or less, treated dogs can be readily re-infected with adult worms and resume CE transmission.

Prophylaxis (Prevention)

A single effective vaccine has been developed for livestock animals – see Section 6 for more details.

Options and strategies for control programs at national, sub-national or regional level

Control measures for echinococcosis are aimed at breaking the cycle of transmission and involve four main components:

1. Control of non-owned dogs. In many parts of the world, feral or semi-feral dogs contribute significantly to CE transmission. However, in most parts of the world it is difficult or impossible to implement control measures in these animals. There is no effective vaccine for *E. granulosus* in dogs and little prospect that an effective vaccine could be developed (see Section 6). Euthanasia of dogs is resisted strongly by the communities in many areas where CE is endemic. Treatment of the animals with praziquantel is impractical due to the frequency with which dog treatments need to be implemented for this control measure to be effective.

2. Prevention of dogs gaining access to infected offal. Several common practices that occur in areas where CE is highly prevalent contribute to disease transmission. The practice of home slaughter of sheep or goats often leads to unsightly, infected offal being deliberately given to dogs. Otherwise, lax disposal practices with home slaughtered animals also provides access for dogs to infected offal. Formal abattoirs often exhibit poor control practices over condemned materials such that dogs gain access to these. Preventing each of these practices can reduce transmission of CE, however changing people's behavior concerning home slaughter has been found to be very difficult except in relatively wealthy, highly literate societies.

3. Treatment of dogs. Frequent treatment of dogs with praziquantel has been the cornerstone of most efforts to control CE. However, the high frequency with which the drug must be administered has been a major limitation to most CE control programs that have relied on dog treatment. Furthermore, dog dosing by the animal owners has been found to be very unreliable, and the cost of employing staff to directly implement a dog dosing practice has proven prohibitive in most CE control programs.

4. Quarantine of infected livestock. This practice has been used in the final phases of a small number of control programs that have been effective and where the programs have brought the disease towards elimination. It is not practical for livestock quarantine to play a more extensive role in CE control, particularly because of the inadequacy of available diagnostic methods for CE in livestock.

5. Vaccination. Data are becoming available from the first field applications of the EG95 livestock vaccine in a CE control program [44]. Details are provided in Section 6.

Mathematical modelling of the transmission parameters for CE using various CE control options including the EG95 vaccine, showed that the use of vaccination together with relatively infrequent treatment of dogs, provided the optimal level of control with a relatively minimal cost in terms of the interventions involved. Vaccination plus dog treatments would be effective in situations where it is very difficult or impossible to achieve some other measures, such as control of stray dogs [45].

Control of echinococcosis in wildlife

Control measures applied to wildlife animals forms the basis on which efforts have been made to reduce transmission of AE in Europe (use of praziquantel-containing baits for European foxes). Although wildlife is known to contribute to some degree to CE transmission in many parts of the world, nowhere in the world where the disease is highly endemic is wildlife transmission considered to be a major source of human infection and CE control measures are more appropriately directed towards domestic transmission of the disease rather than sylvatic transmission. An implication of the transmission of CE via wildlife is that elimination of CE is not feasible in many parts of the world due to sylvatic transmission. For example, E. *granulosus* has been introduced to the Australian continent through the importation of sheep some 200 years ago and the parasite has become endemic down the eastern seaboard, transmitted by wild dogs (dingos) and macropod marsupials. The disease constantly spills over to infect livestock and humans living adjacent to forest areas where the sylvatic transmission occurs [46].

Table 5: Official status, official programs and treatment for echinococcosis/hydatidosis in the countries of interest. Information provided by the questionnaire sent to the DG/DVS as part of this monograph. Replies were not received from India, Indonesia, Burkina Faso, Ethiopia, Madagascar, Mozambique, Senegal and South Africa.

Country	Notifiable (yes/no)	Official surveillance[1] program (yes/no) (if yes, active or passive)	Official control[2] program (yes/no)	Treatment (Chemotherapy)	
				Treatment authorised (yes/no)	Frequently practiced (yes/no)
ASIA					
Bangladesh	Yes	No	No	-	-
Myanmar (Burma)	No	No	No	No	Yes
Nepal	No	Yes, passive	No	Yes	Yes
Vietnam	No	No	No	-	-
AFRICA					
Côte d'Ivoire (Ivory Coast)	Yes	Yes, passive but active if outbreaks	No	-	-
Kenya	Yes	Yes, passive at abattoir	No	Yes	Yes
Malawi	No	No	No	N/A	N/A
Mali	N/A	N/A	N/A	N/A	N/A
Rwanda	-	-	-	-	-
Tanzania	Yes	Yes, active	No	No	No
Uganda	No	No	No	N/A	N/A
Zambia	Yes	Yes, passive	Yes	Yes	N/A

Table 6: Official status, official programs and treatment for echinococcosis/hydatidosis in the countries of interest. Information provided by the questionnaire sent to the DG/DVS as part of this monograph. Replies were not received from India, Indonesia, Burkina Faso, Ethiopia, Madagascar, Mozambique, Senegal and South Africa.

Country	Vaccination			
	Compulsory vaccination (yes/no)	Who pays for the vaccine (Government, farmers, combination, others-specify)	Who delivers the vaccine (official, private vaccinators or both)	Species vaccinated (cattle, sheep, goats, pigs, poultry)
ASIA				
Bangladesh	No	-	-	-
Myanmar (Burma)	No	-	-	-
Nepal	No	-	-	-
-Vietnam	No	-	-	-
AFRICA				
Côte d'Ivoire (Ivory Coast)	No	-	-	-
Kenya	N/A	N/A	N/A	N/A
Malawi	No	N/A	N/A	N/A
Mali	N/A	N/A	N/A	N/A
Rwanda	-	-	-	-
Tanzania	No	Not done	Not done	Not done
Uganda	No	Never vaccinated	N/A	N/A
Zambia	No	N/A	N/A	N/A

Vaccines Available

Commercial vaccines manufactured in Africa and Asia

There are no vaccines listed under The Center for Food Security and Public health, Iowa State University (**www.cfsph.iastate.edu/vaccines/index.php** and Vetvac (**www.vetvac.org)** databases.

Commercial vaccines imported into Africa and Asia (countries of interest)

There are no commercial vaccines for hydatid licensed to use in the countries of interest, and there is no information about the use of unlicensed vaccines in the focus countries.

Combination vaccines

No combination vaccines are in use or available for echinococcosis. However, combination of EG95 together with other livestock vaccines, particularly clostridial vaccines, would be an obvious advantage and could solve the difficulties experiences with adoption of EG95 vaccination due to the lack of incentive for livestock owners to choose to vaccinate against CE.

Characteristics of Ideal Vaccine Candidates for Smallholders

The Target Product Profiles (TPPs) reflect the availability and utility of current agents and incorporate features that will be necessary to improve on the current products and to address unmet needs, taking into account the particular requirements of the poorest livestock keepers.

The TPPs are more robust when they include the opinions and consider the needs of the different stakeholders. While efforts have been made to encompass them, the TPP showed in Table 7 below, should be considered a proposal, a live document subject to improvements.

Minimum characteristics are based on information available concerning the EG95 vaccine produced at UM, and Hidatil EG95 produced by Tecnovax (Argentina).
http://www.sani.com.ar/producto_imprimir.php?id_producto=5643 . Note that UM is a freeze dried vaccine, while the one from Argentina has an oil adjuvant.

Table 7: Official status, official programs and treatment for echinococcosis/hydatidosis in the countries of interest. Information provided by the questionnaire sent to the DG/DVS as part of this monograph. Replies were not received from India, Indonesia, Burkina Faso, Ethiopia, Madagascar, Mozambique, Senegal and South Africa.

	Attribute	Minimum (current available vaccine)	Ideal
1	Antigen	Immunogen with protective antigens for *E. granulosus s s* (Genotypes 1-3)	Immunogen with protective antigens for *E. granulosus* ALL genotypes.
2	Indication for use	For active immunization of sheep and goats.	For active immunization of sheep, goats, cattle, camels and pigs.
3	Recommended species	Sheep and goats.	All susceptible livestock, including susceptible wildlife.

4	Recommended dose	1 ml (50µg recombinant protein)	Same dose for all species (1 or 2 ml)
5	Pharmaceutical form	Freeze dried or liquid	Ready to use solution/suspension
6	Route of administration	SC or IM	SC, Intramuscular or oral (bait vaccine, this last route, very important for wildlife)
7	Regimen - primary vaccination	Two doses, 30 days apart.	Single lifetime dose
8	Regimen - booster	Revaccinate annually.	Lifelong immunity after primary vaccination
9	Epidemiological relevance	Protection against *E. granulosus*	Protection against *B. anthracis* and all possible mutants
10	Recommended age at first vaccination	From 3 months of age	From 1-2 months of age, when other vaccines are applied.
11	Onset of immunity		<7 days (very important for outbreaks)
12	Duration of immunity	1 year	Lifelong immunity
13	Expected efficacy	To prevent disease & prevent transmission.	To prevent infection and transmission in 100% of the animals.
14	Expected safety	It can generate a mild local reaction.	No post-vaccinal reactions at any age. Safe for pregnant animals at any stage. Safe for all sexes at any age.
15	Withdrawal period	Nil	Nil for milk and meat
16	Special requirements for animals	Do not vaccinate un-healthy animals.	Vaccinate all animals

17	Special requirements for persons	None	None
18	Package size	100 – 125 doses	Multiple pack size from 5 doses
19	Price to end user	Tecnovax is selling vaccine to a region in Chile at USD 1,80 – 1,90 per dose (extremely high).	< USD 0.10
20	Storage condition and shelf-life as packaged for sale	Stable at 4-8°C for 24 months	Stable at 30°C for 24 months
21	In-use stability		24 hours or greater
22	Other: potential combinations		Combined with clostridial vaccines or any commonly used vaccine in lambs.

Limitations

Scientific quality: The publications and data from the different research groups, should be carefully evaluated. The use of good science and good experimental design with use of proper controls, adequate numbers, suitable challenge model, reproduction of results by them and by independent groups, and appropriate analysis has not been verified for this monograph. If any of these projects were to be pursued, a detailed peer review taking into account the above considerations is strongly recommended.

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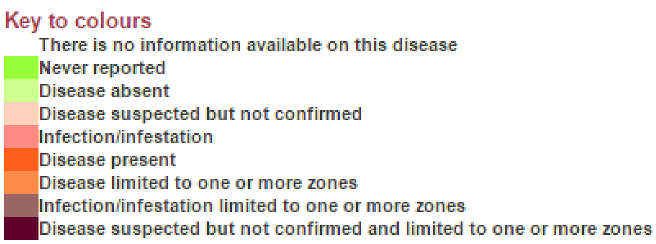
ANNEX 1: Additional data on disease presence and incidence

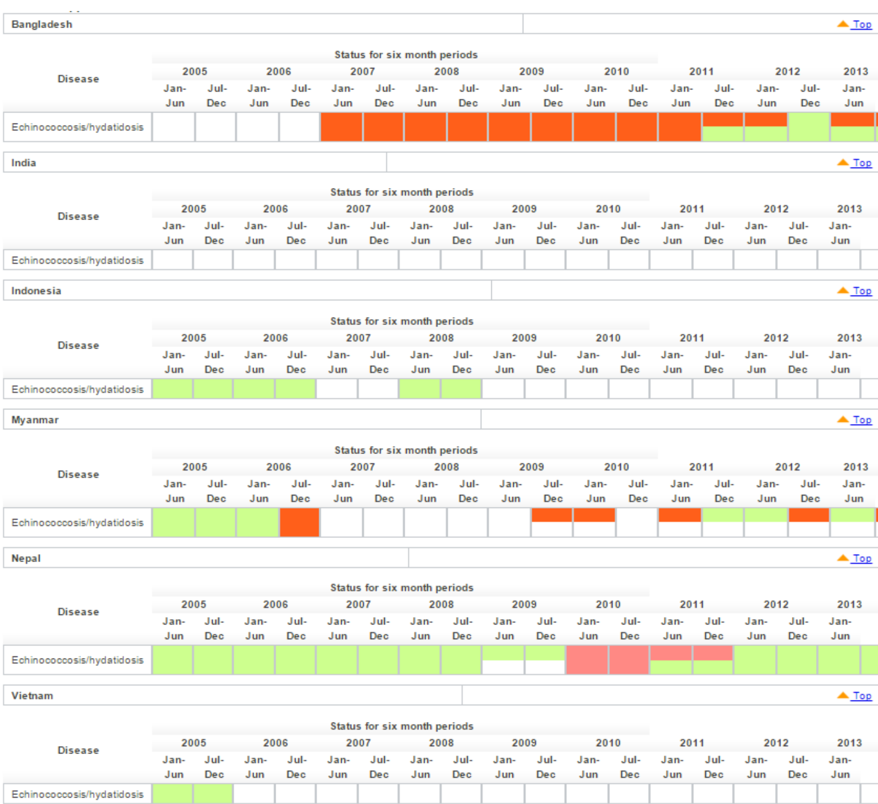
Reports to OIE on echinococcosis/hydatidosis:

Note: The OIE changed the definitions of the diseases in 2014. Therefore, there are 2 graphs for each region. One covering from 2005-2013 (that does not differentiate the different types of *Echinococcus*), and another one for 2014-2015, specific for *E. granulosus*.



When different animal health statuses between domestic and wild animal population are provided, the box is split in two: the upper part for domestic animals, and the lower part for wild animals.

Echinococcosis/hydatidosis in Asia: Bangladesh, India, Indonesia, Myanmar, Nepal and Vietnam (2005-2013)



Infections with *E. granulosus* in Asia: Bangladesh, India, Indonesia, Myanmar, Nepal and Vietnam (2014-2015)

Bangladesh — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

India — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Indonesia — Top

No information

Myanmar — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)	NA	NA	

Nepal — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Vietnam — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Echinococcosis/hydatidosis in Western Africa: Burkina Faso, Ivory Coast, Mali and Senegal (2005-2013)

Burkina Faso — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Cote D'Ivoire — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Mali — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Senegal — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Infections with *E. granulosus* in Western Africa: Burkina Faso, Ivory Coast, Mali and Senegal (2014-2015)

NA Not applicable

Burkina Faso	Top

No information

Cote D'Ivoire	Top

Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)	NA	NA	NA

Mali	Top

Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)			

Senegal	Top

No information

Echinococcosis/hydatidosis in Eastern Africa: Ethiopia, Kenya, Rwanda, Tanzania and Uganda (2005-2013)

Ethiopia	Top

Disease	Status for six month periods																
	2005		2006		2007		2008		2009		2010		2011		2012		2013
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcosis/hydatidosis																	

Kenya	Top

Disease	Status for six month periods																
	2005		2006		2007		2008		2009		2010		2011		2012		2013
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcosis/hydatidosis																	

Rwanda	Top

Disease	Status for six month periods																
	2005		2006		2007		2008		2009		2010		2011		2012		2013
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcosis/hydatidosis																	

Tanzania	Top

Disease	Status for six month periods																
	2005		2006		2007		2008		2009		2010		2011		2012		2013
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcosis/hydatidosis																	

Uganda	Top

Disease	Status for six month periods																
	2005		2006		2007		2008		2009		2010		2011		2012		2013
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcosis/hydatidosis																	

Infections with *E. granulosus* in Eastern Africa: Ethiopia, Kenya, Rwanda, Tanzania and Uganda (2014-2015)

Ethiopia — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Kenya — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Rwanda — Top

No information

Tanzania — Top

Disease	Status for six month periods 2014 Jan-Jun	2014 Jul-Dec	2015 Jan-Jun
Echinococcus granulosus (Infection with)			

Uganda — Top

No information

Echinococcosis/hydatidosis in Southern Africa: Madagascar, Malawi, Mozambique, South Africa and Zambia (2005-2013)

Madagascar — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Malawi — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Mozambique — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

South Africa — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Zambia — Top

Disease	2005 Jan-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun	2007 Jul-Dec	2008 Jan-Jun	2008 Jul-Dec	2009 Jan-Jun	2009 Jul-Dec	2010 Jan-Jun	2010 Jul-Dec	2011 Jan-Jun	2011 Jul-Dec	2012 Jan-Jun	2012 Jul-Dec	2013 Jan-Jun
Echinococcosis/hydatidosis																	

Infections with *E. granulosus* in Southern Africa: Madagascar, Malawi, Mozambique, South Africa and Zambia (2014-2015)

Madagascar			Top
Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)			

Malawi	Top
No information	

Mozambique			Top
Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)	NA	NA	

South Africa			Top
Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)			

Zambia			Top
Disease	Status for six month periods		
	2014		2015
	Jan-Jun	Jul-Dec	Jan-Jun
Echinococcus granulosus (Infection with)			